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(54) **OVER-WIRE IMPLANT CONTRACTION METHODS**

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See application file for complete search history.

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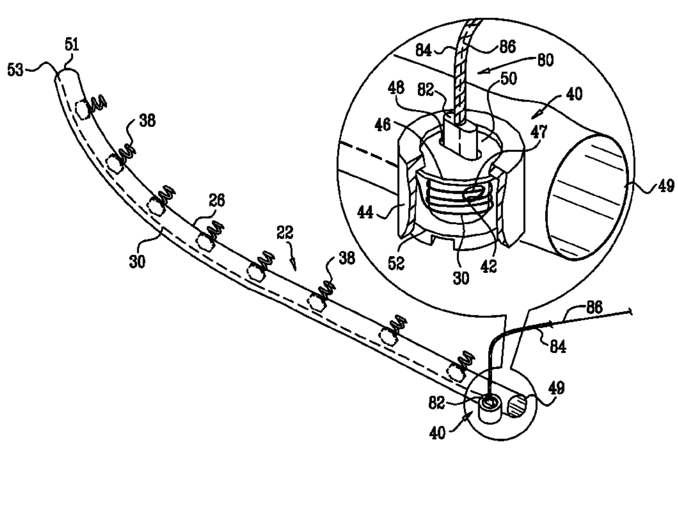
(57) **ABSTRACT**

Apparatus is provided that includes an implant structure, which includes a contracting mechanism, which includes a rotatable structure, arranged such that rotation of the rotatable structure contracts the implant structure. A longitudinal member is coupled to the contracting mechanism. A tool for rotating the rotatable structure is configured to be guided along the longitudinal member, to engage the rotatable structure, and to rotate the rotatable structure in response to a rotational force applied to the tool. Other embodiments are also described.

31 Claims, 34 Drawing Sheets



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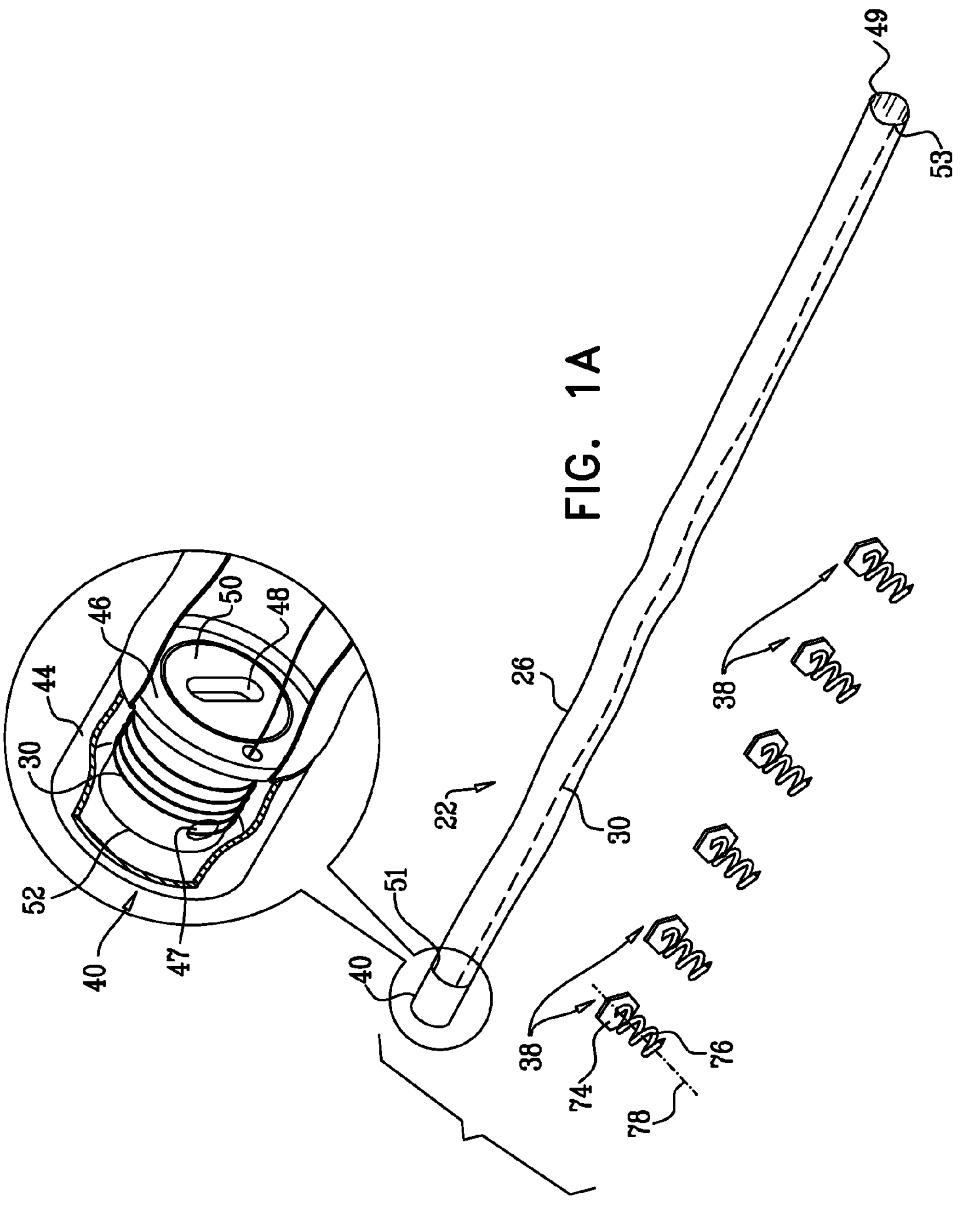

FIG. 1A

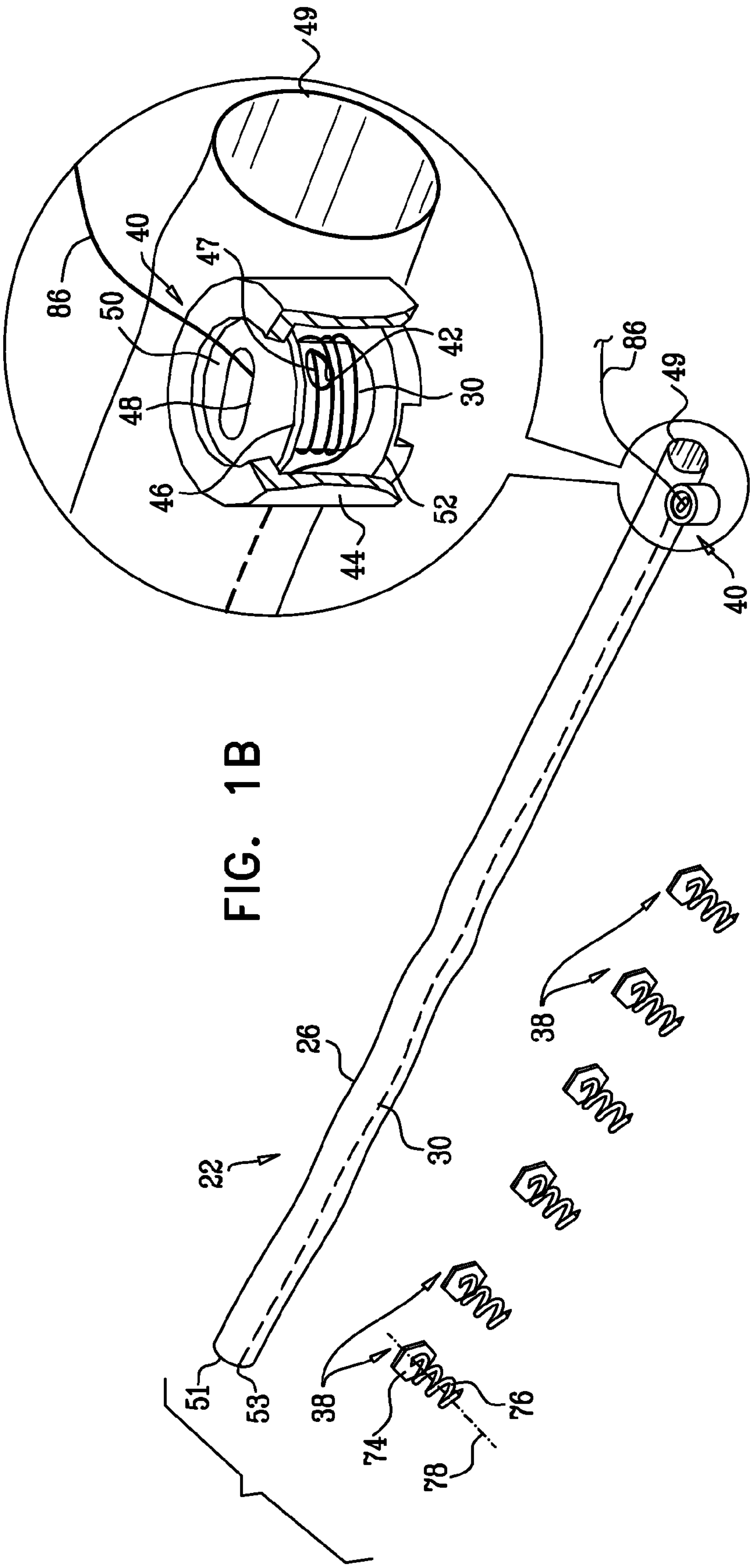

FIG. 1B

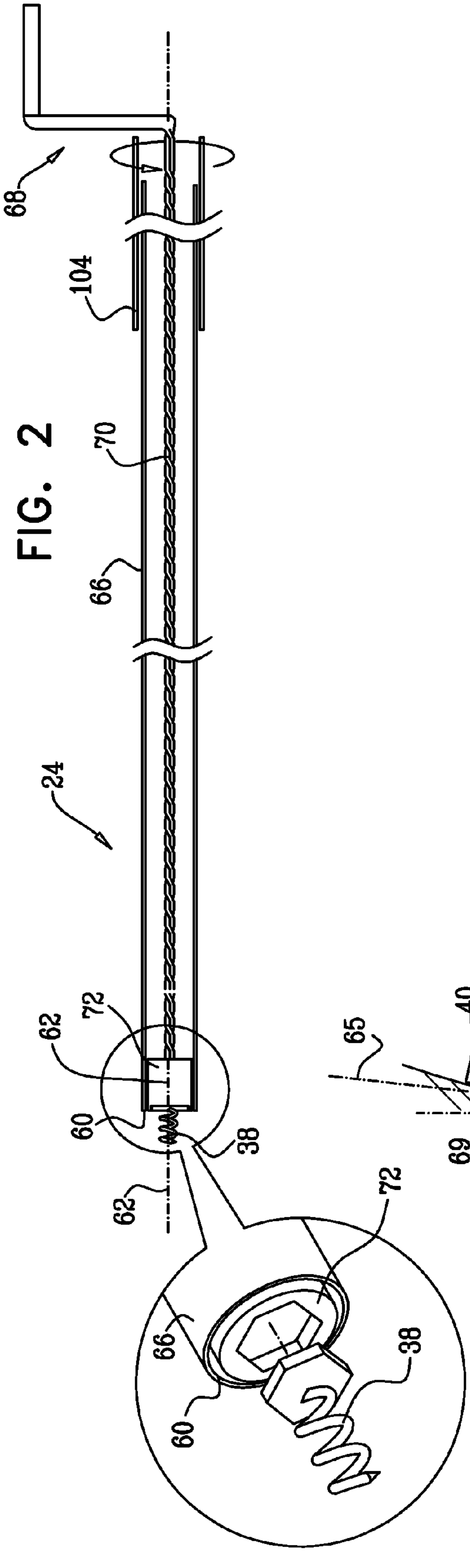

FIG. 2

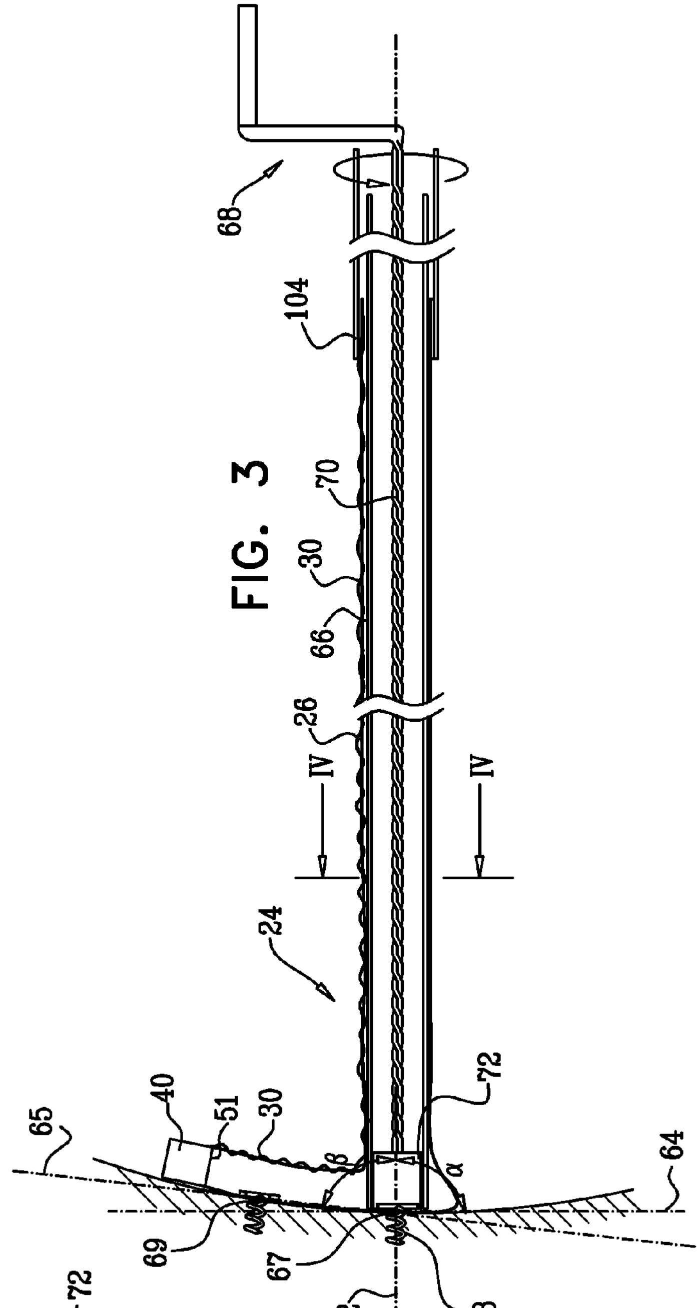

FIG. 3

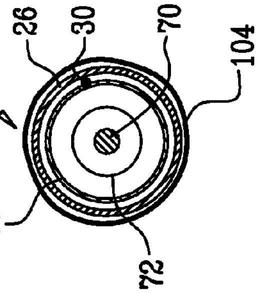

FIG. 4

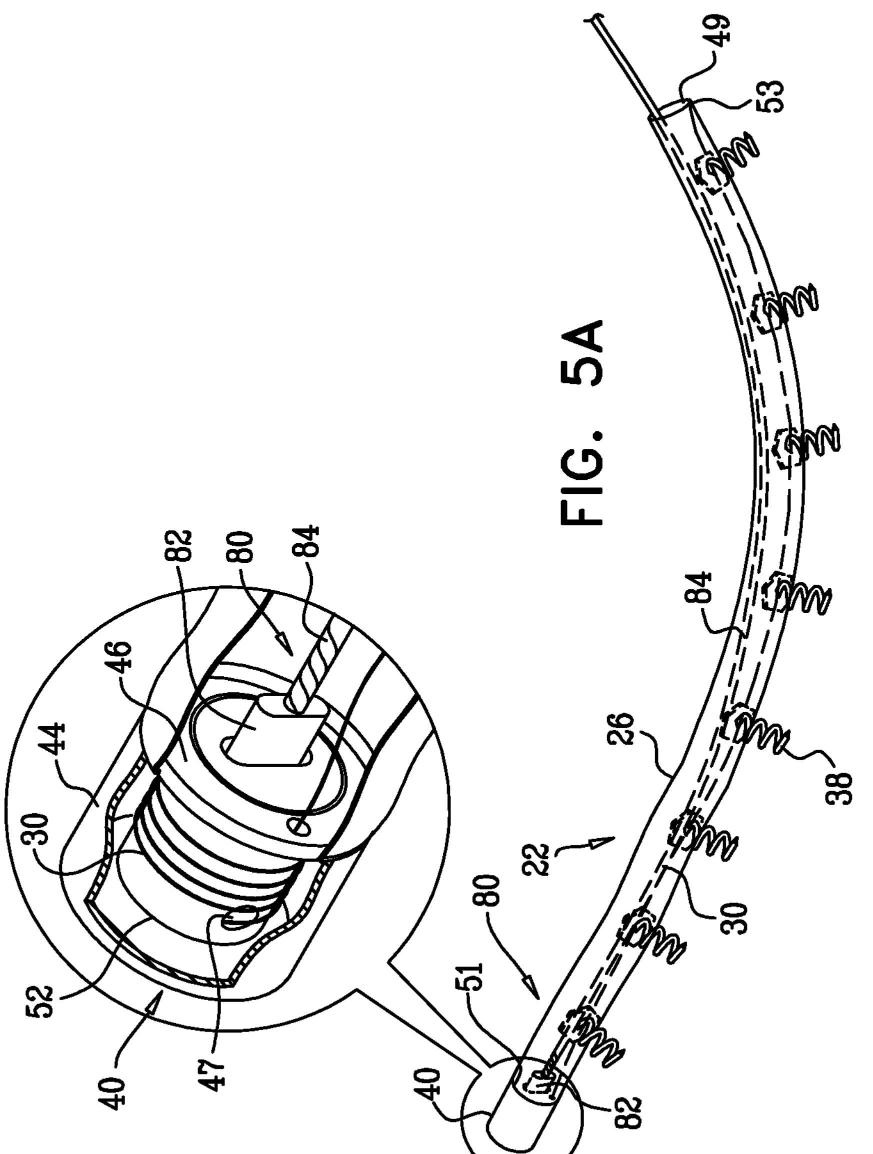

FIG. 5A

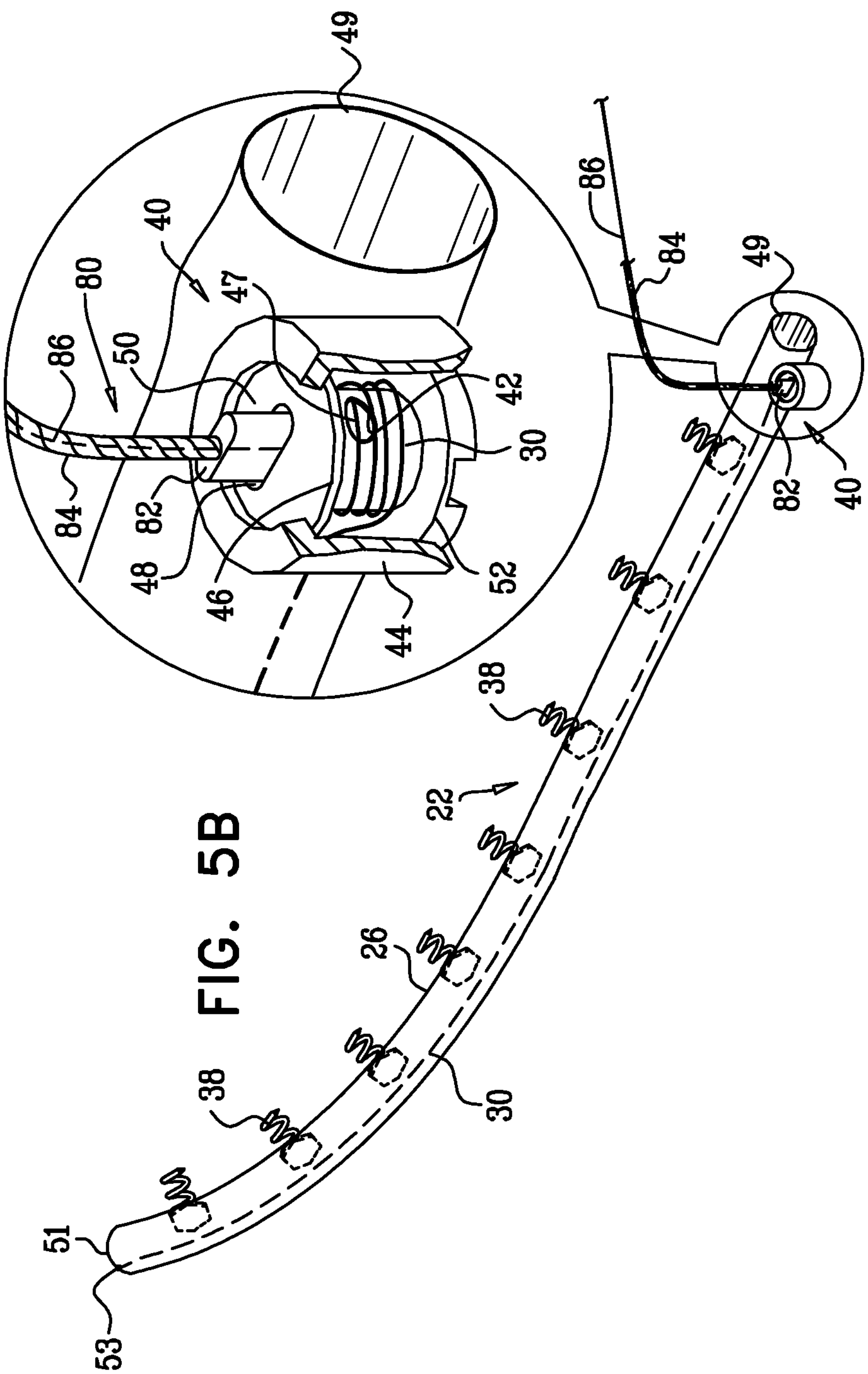
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FIG. 5B

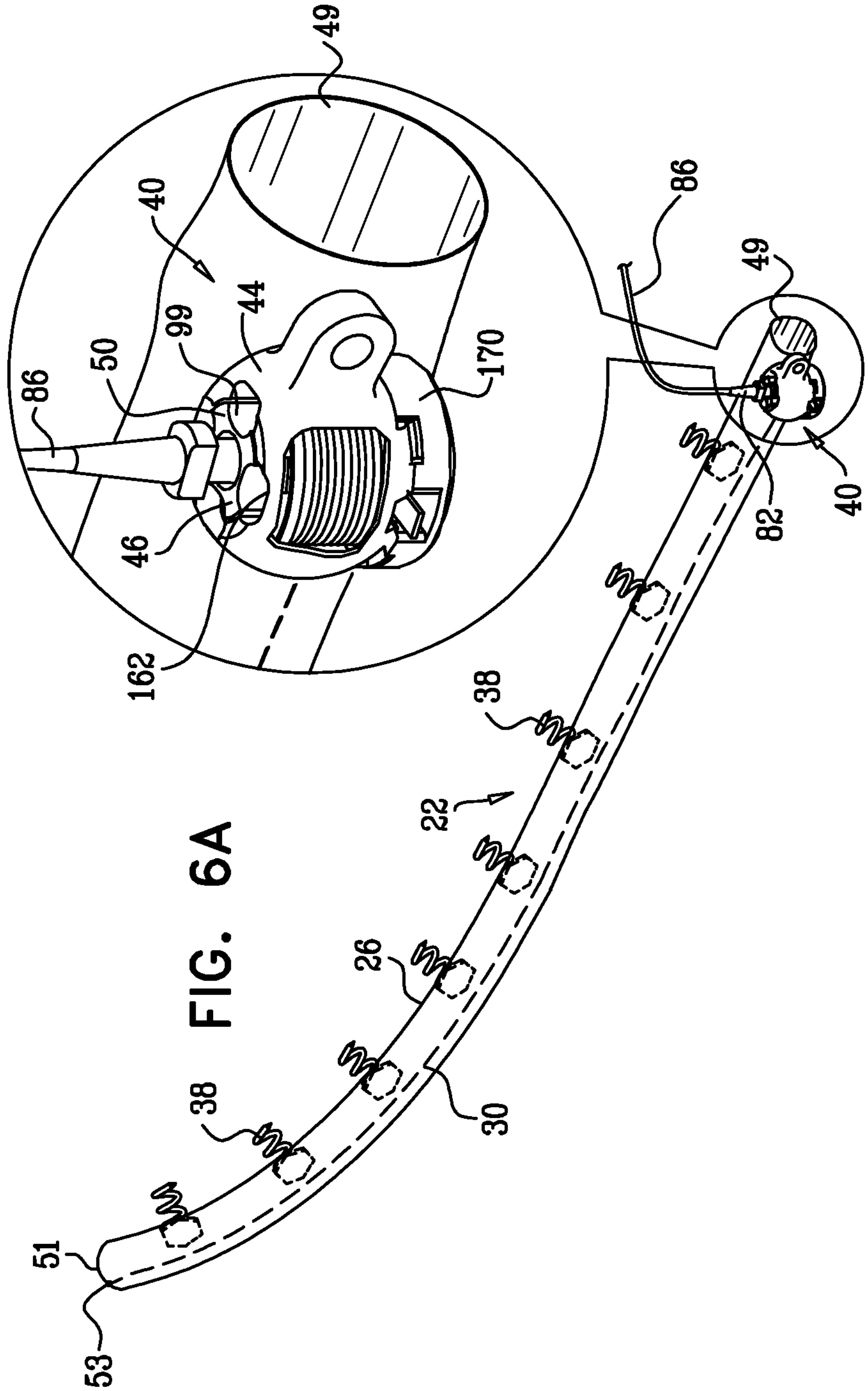
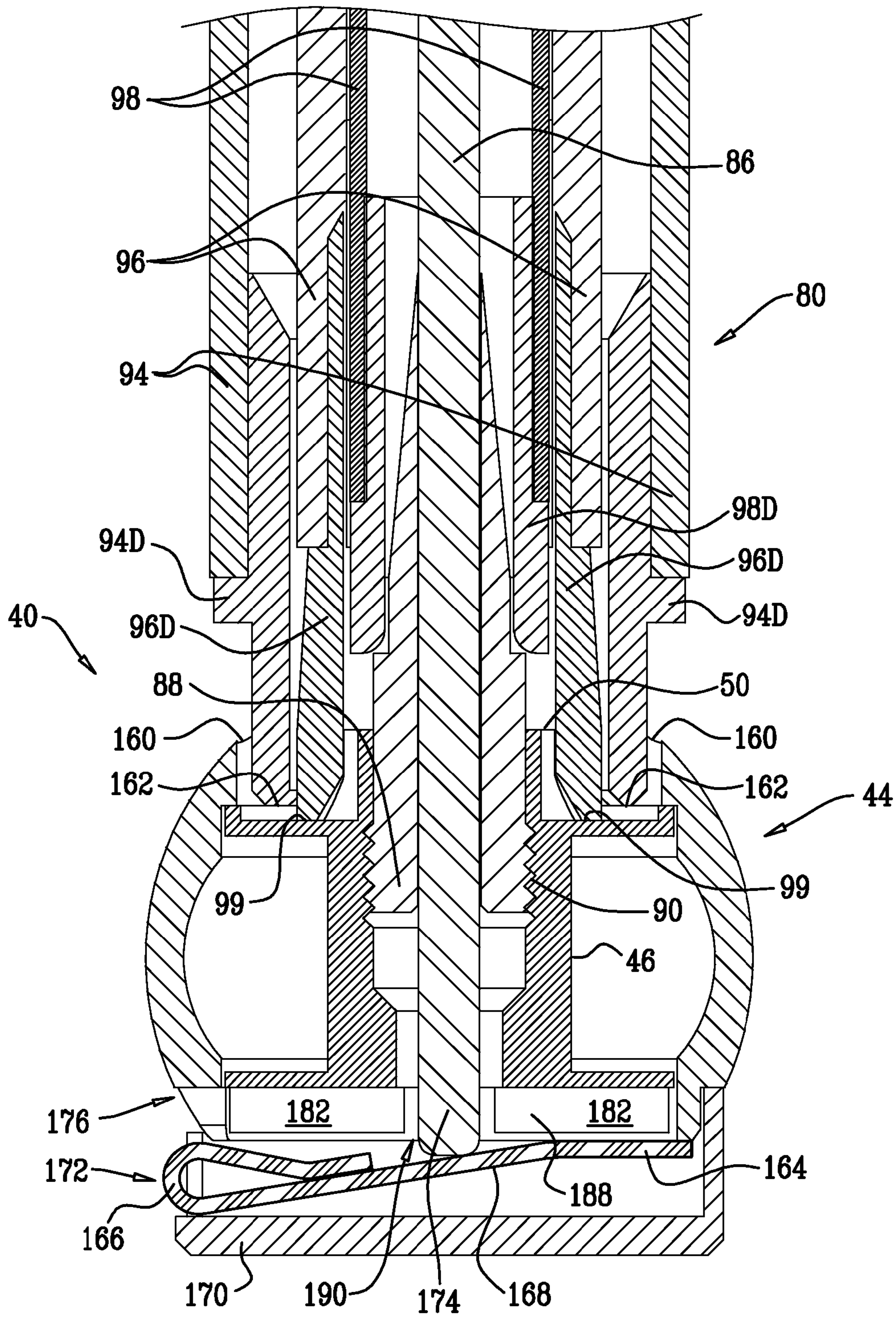


FIG. 6A

FIG. 6B



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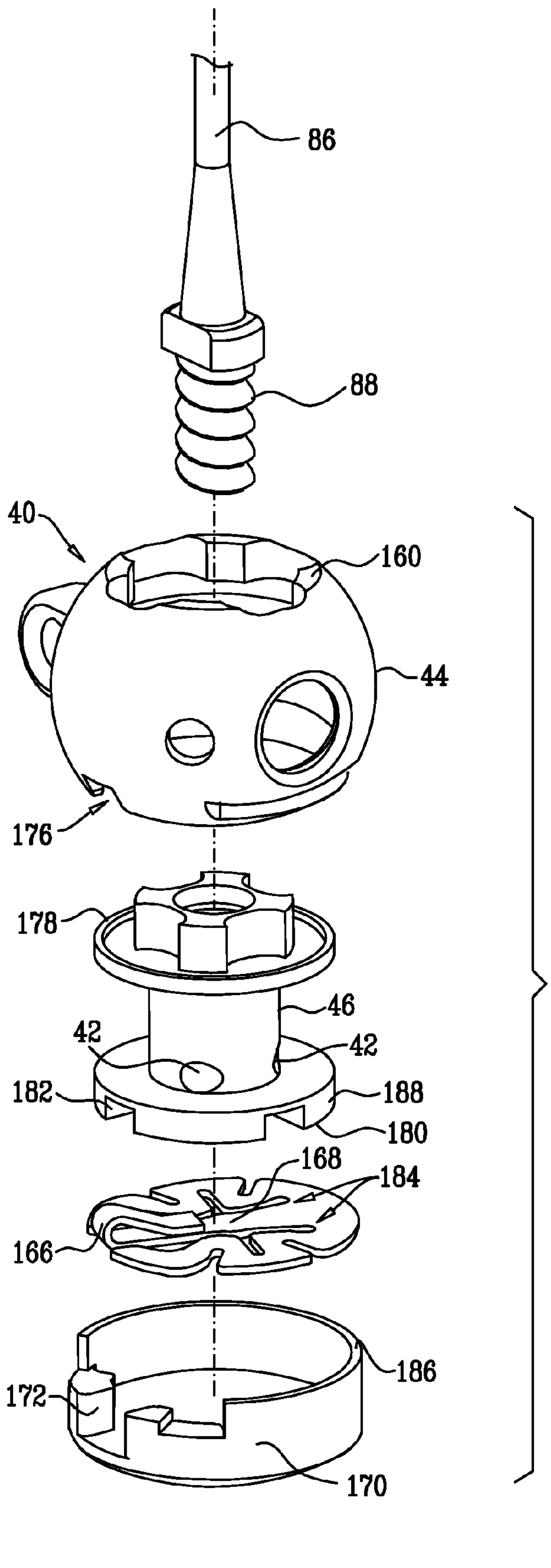

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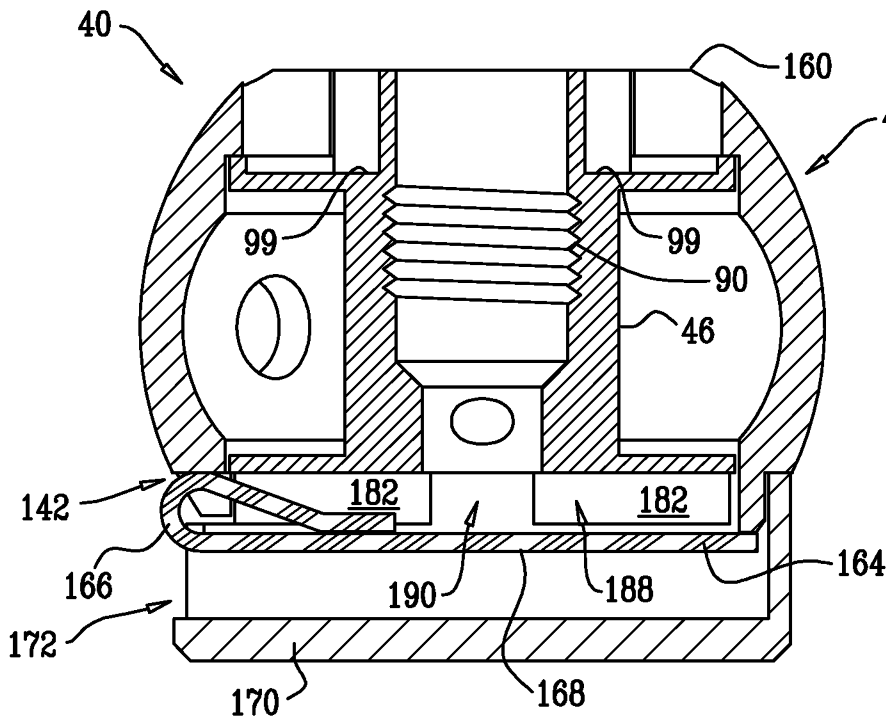
FIG. 7

FIG. 8



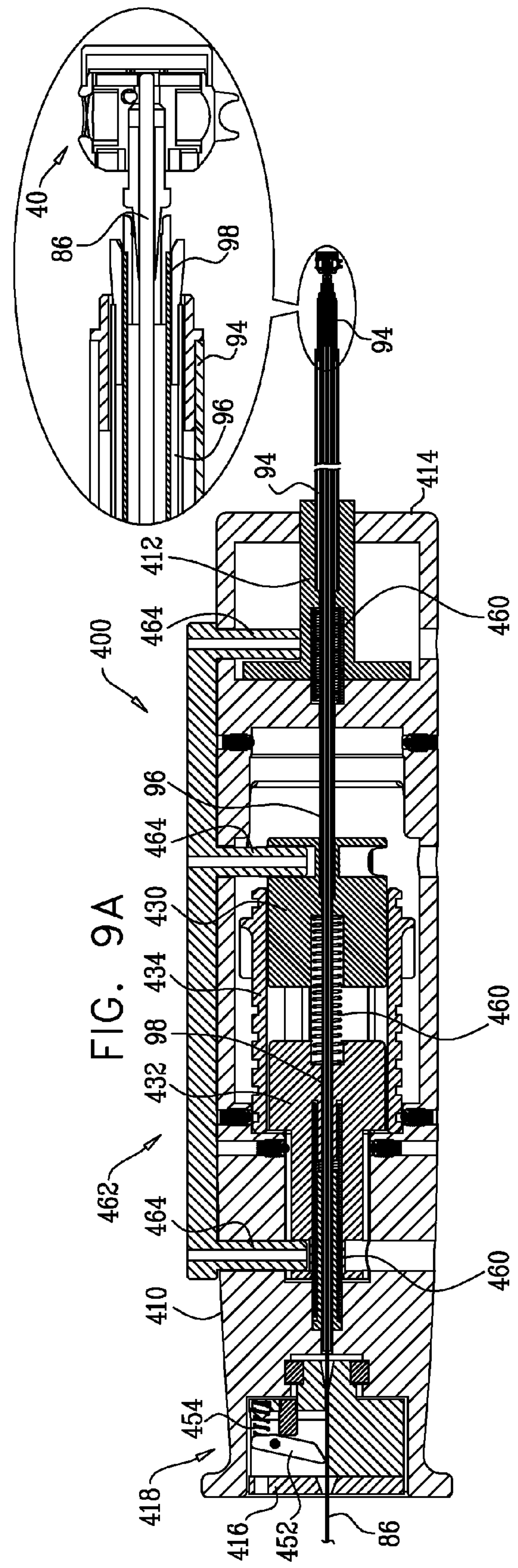

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FIG. 9A

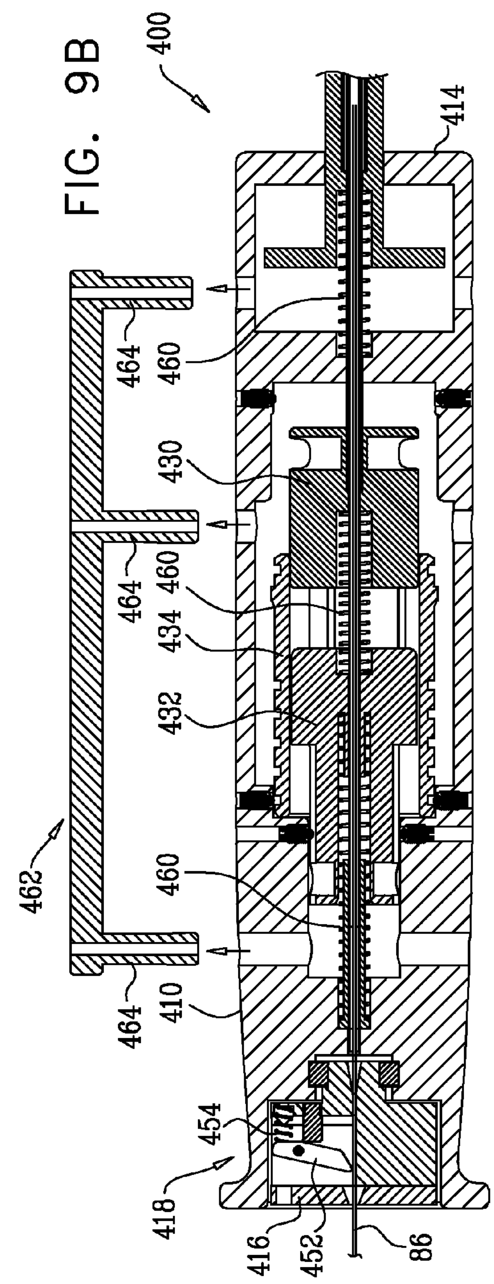
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FIG. 9B

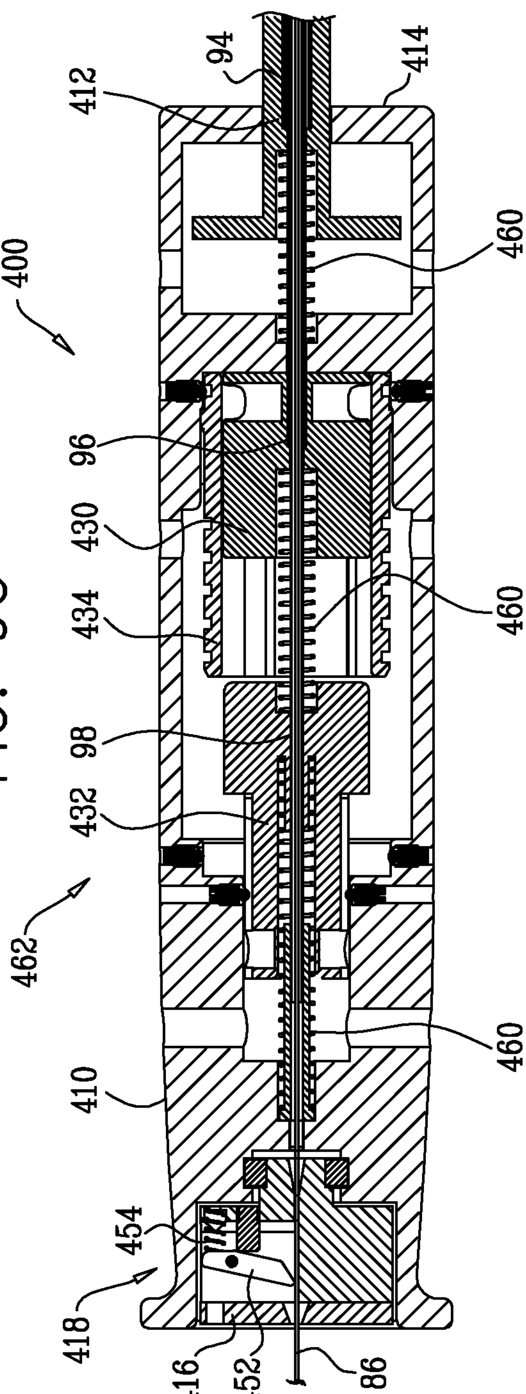
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FIG. 9C

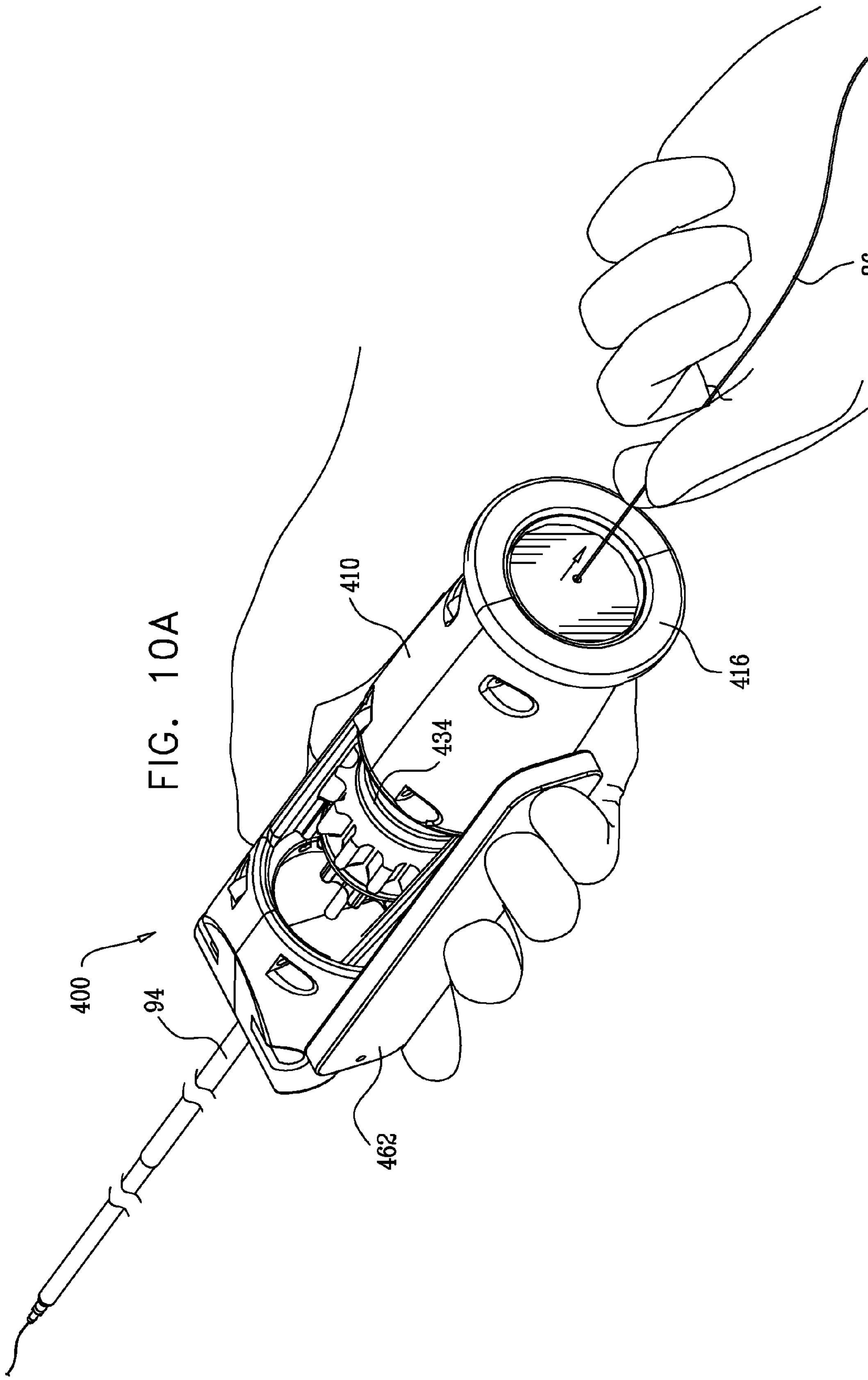

FIG. 10A

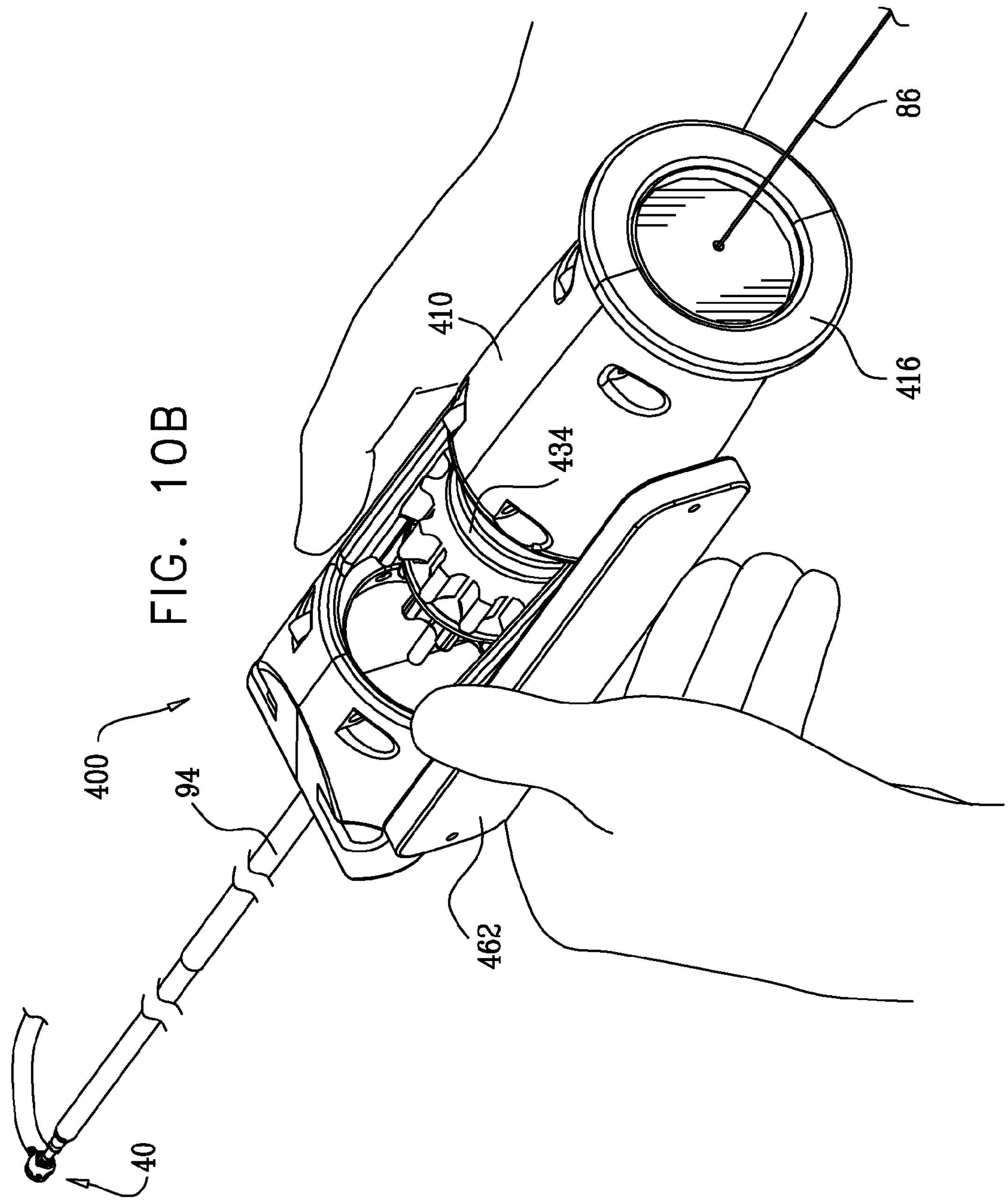

FIG. 10B

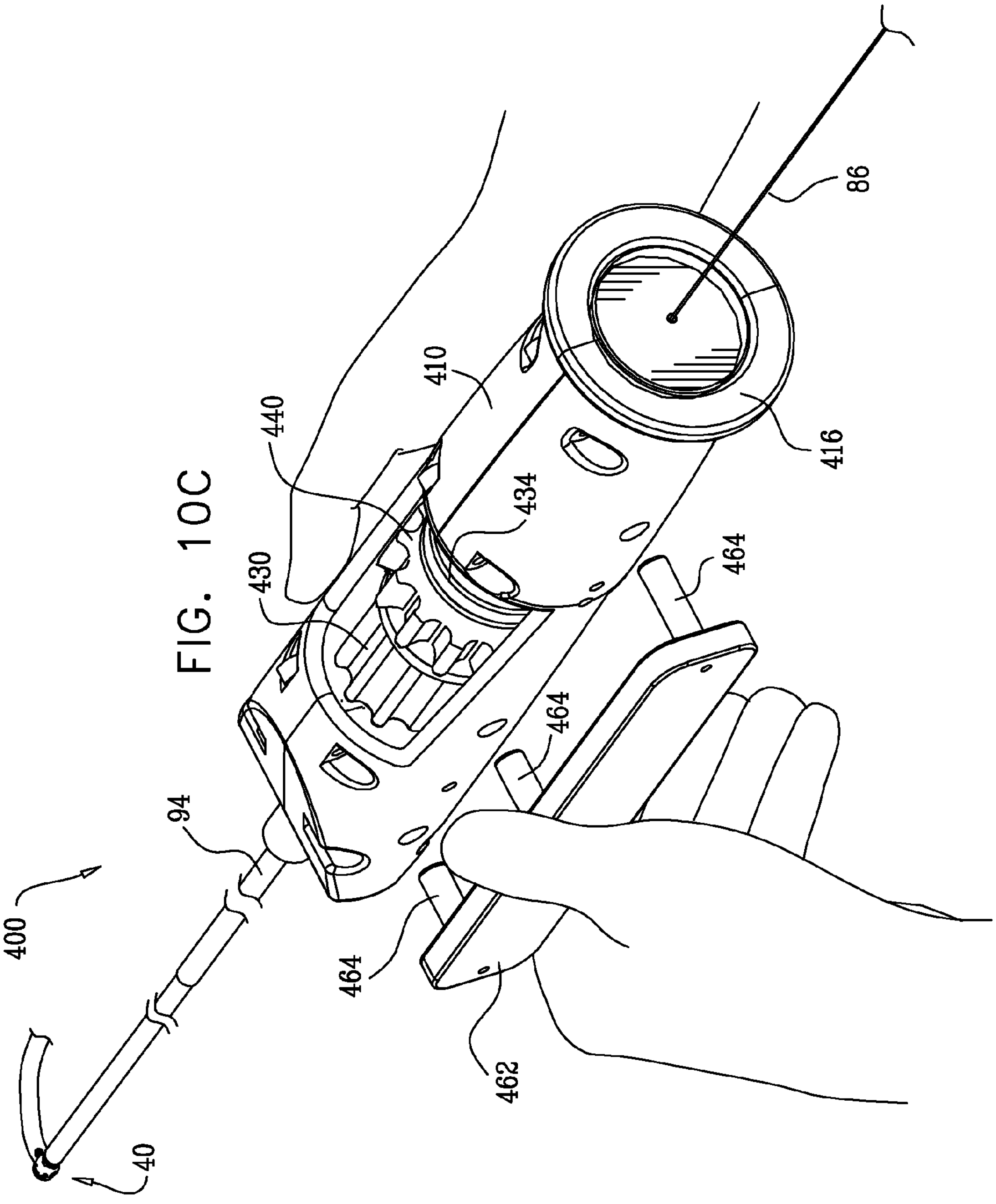

FIG. 10C

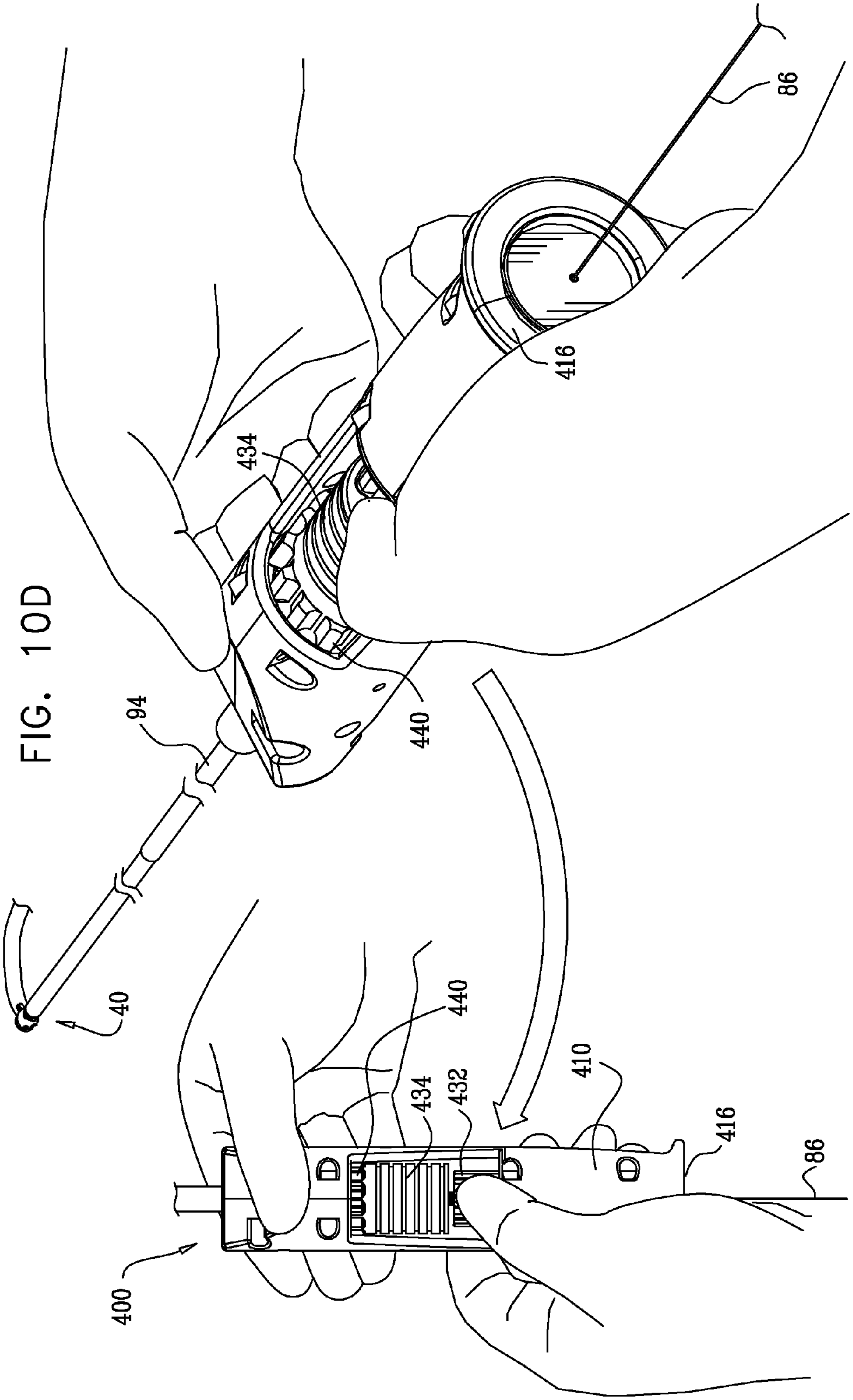

FIG. 10D

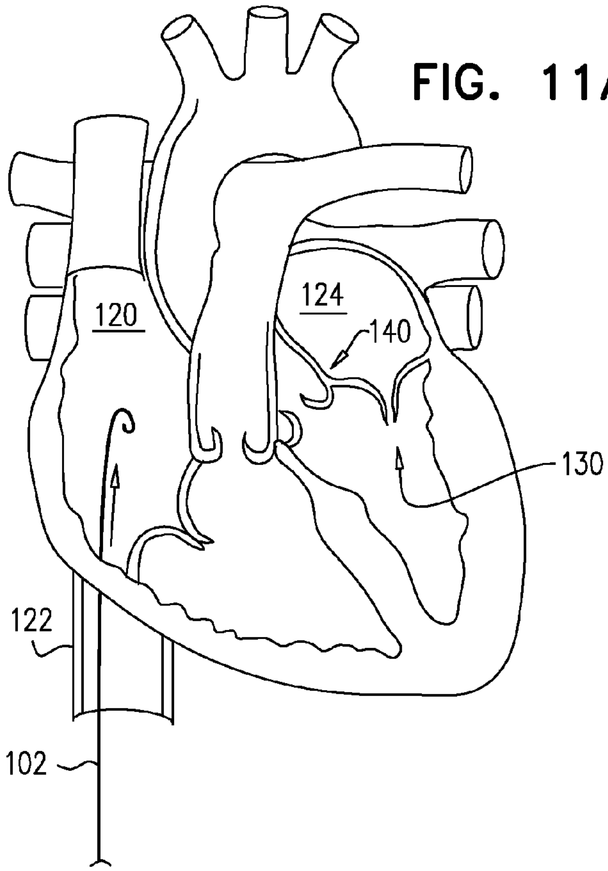

FIG. 11A

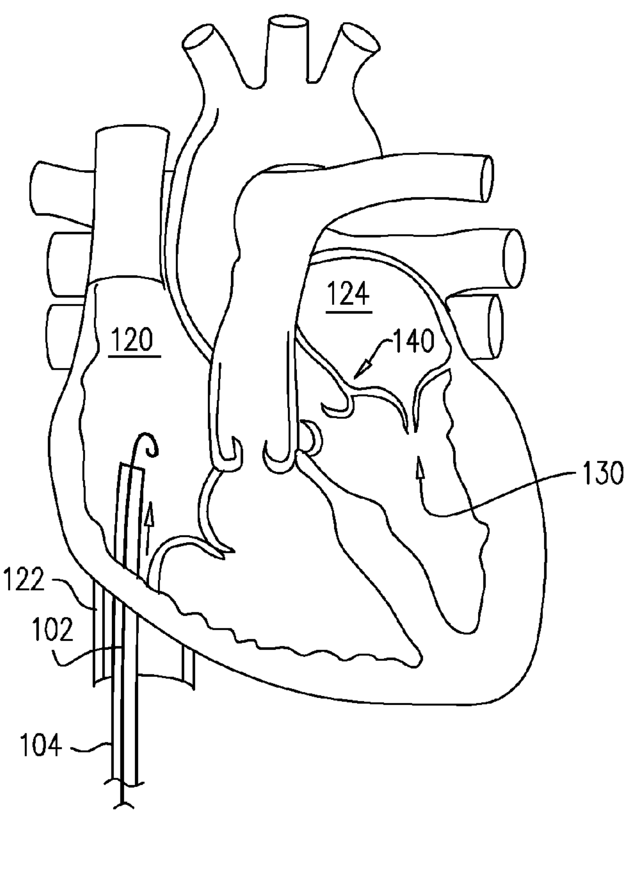

FIG. 11B

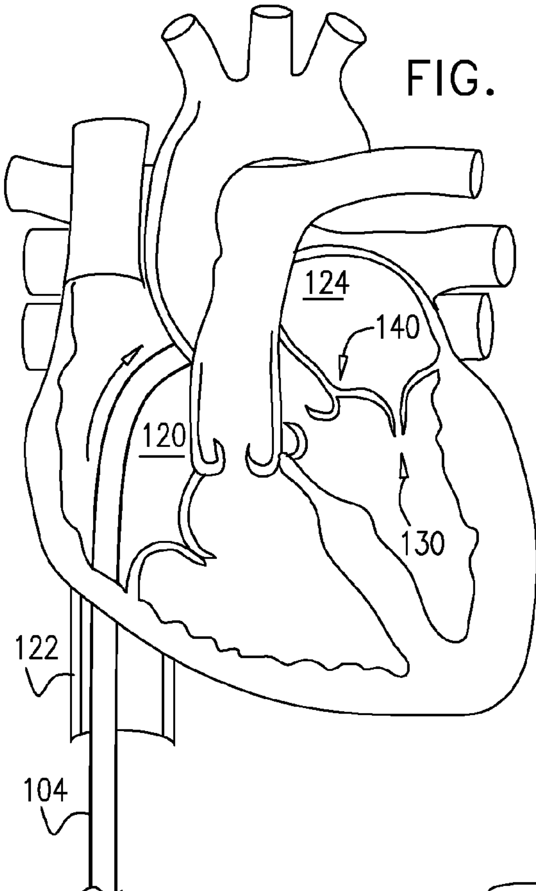

FIG. 11C

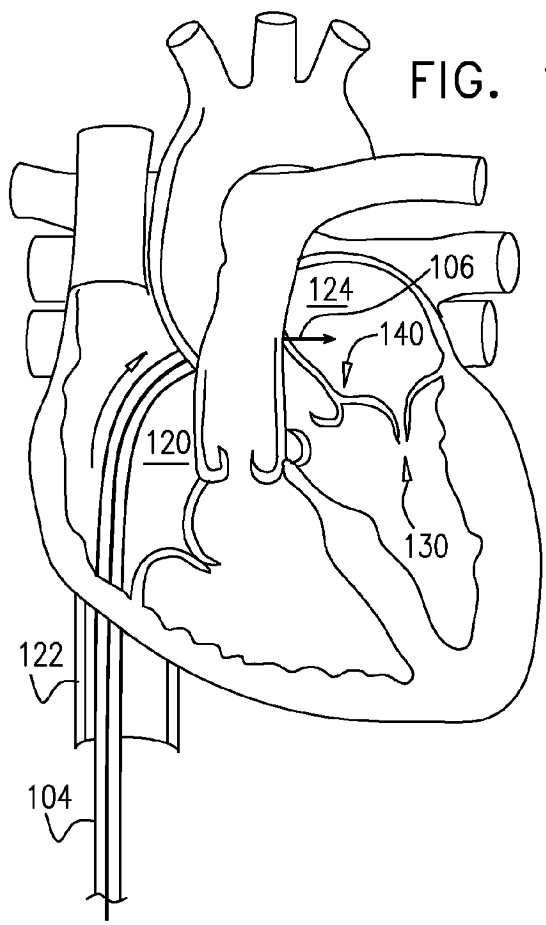

FIG. 11D

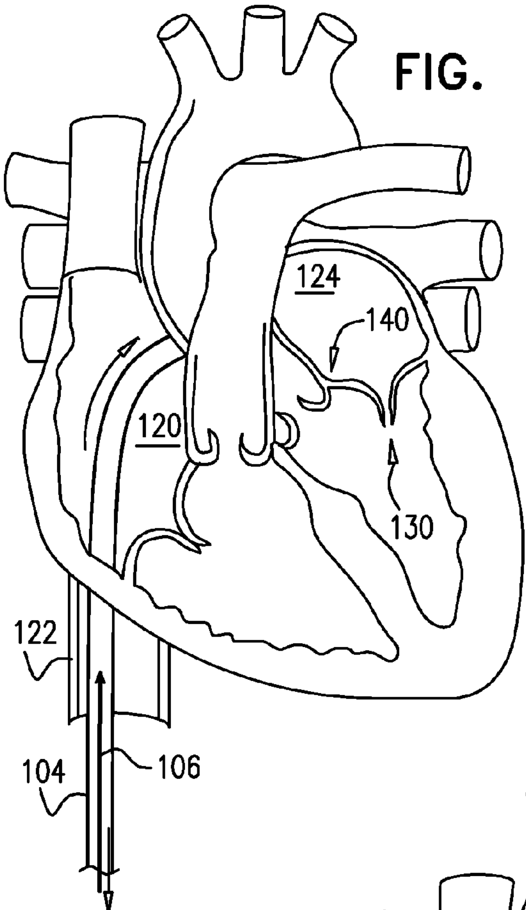

FIG. 11E

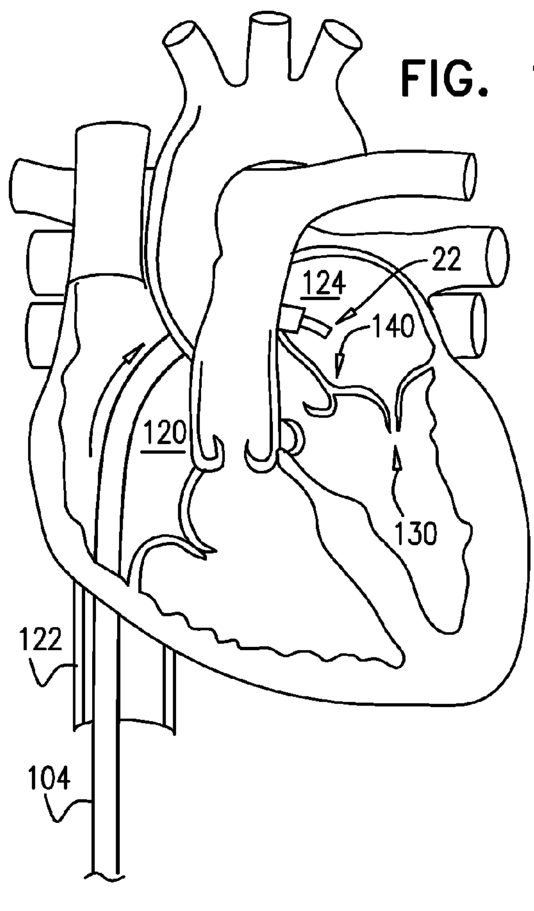

FIG. 11F

FIG. 11G

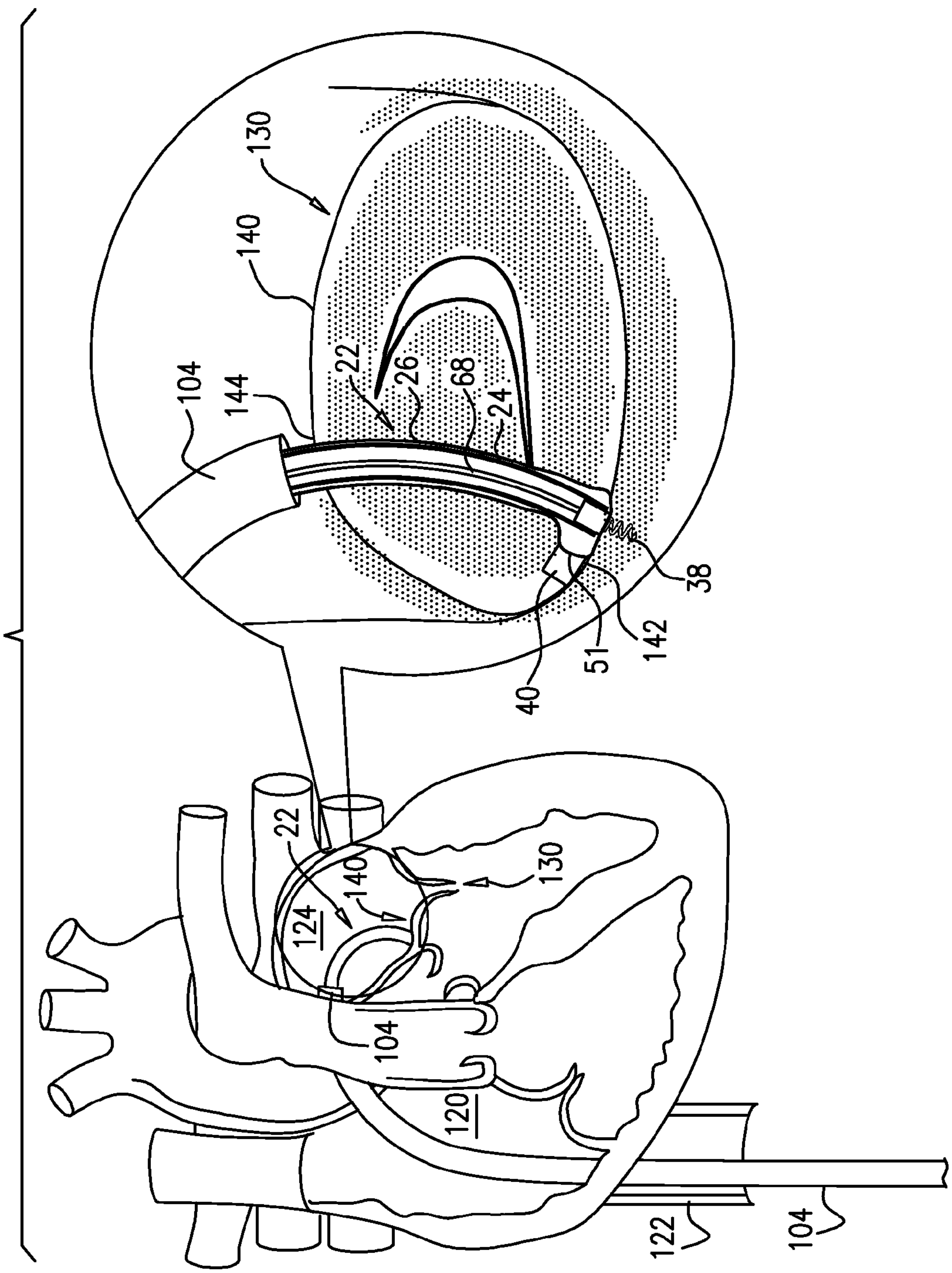
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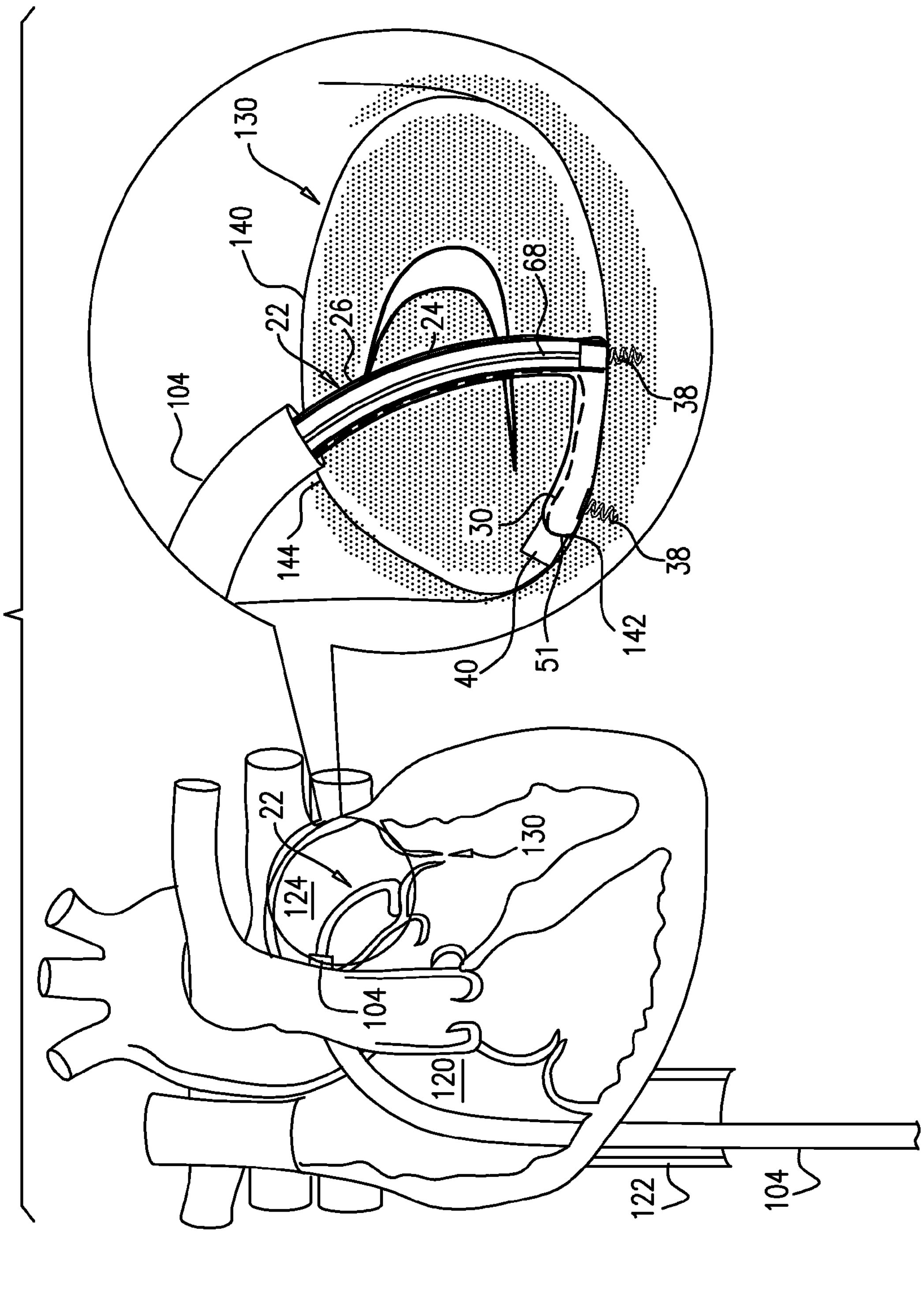
FIG. 11H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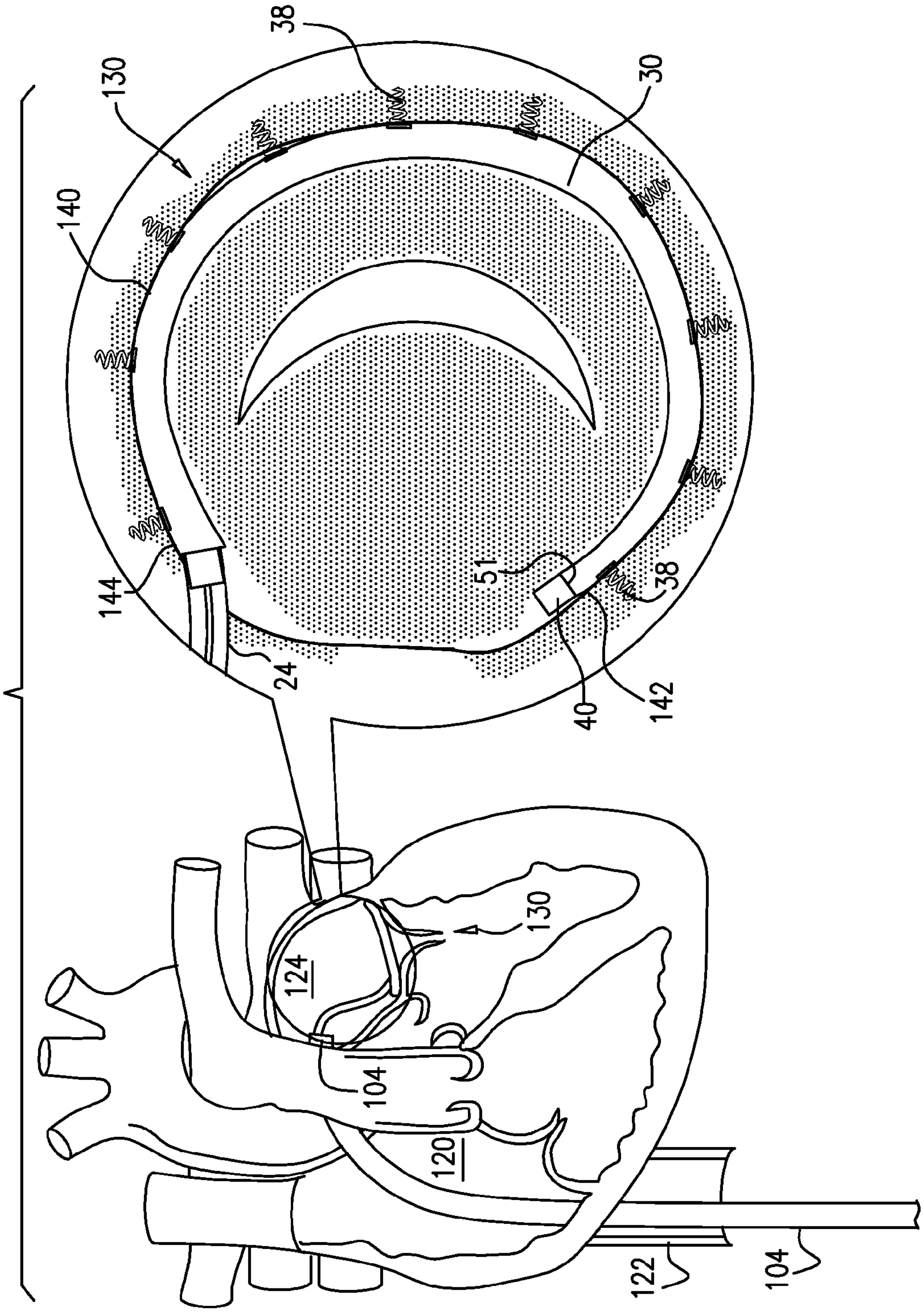

FIG. 11I

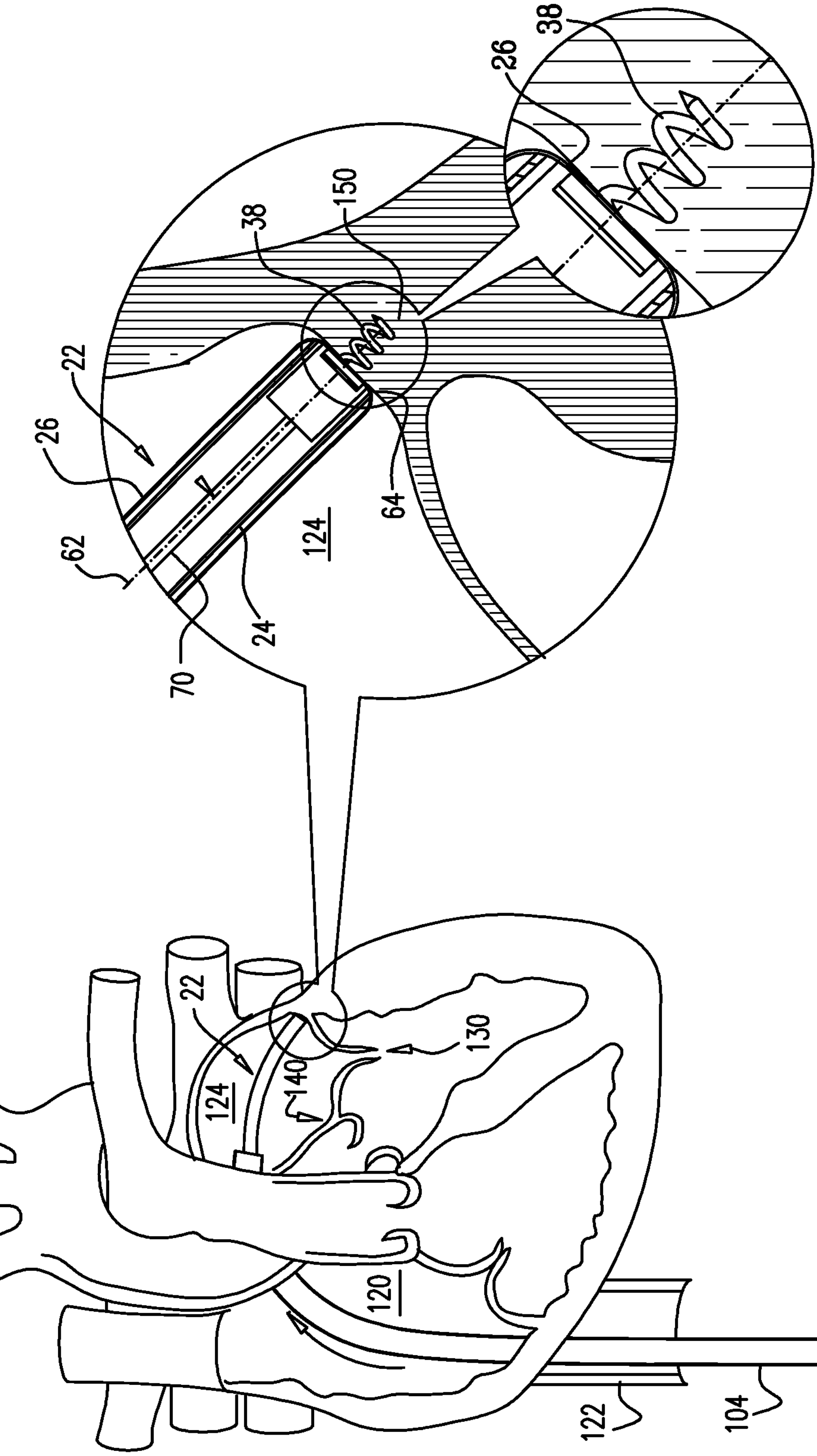

FIG. 12

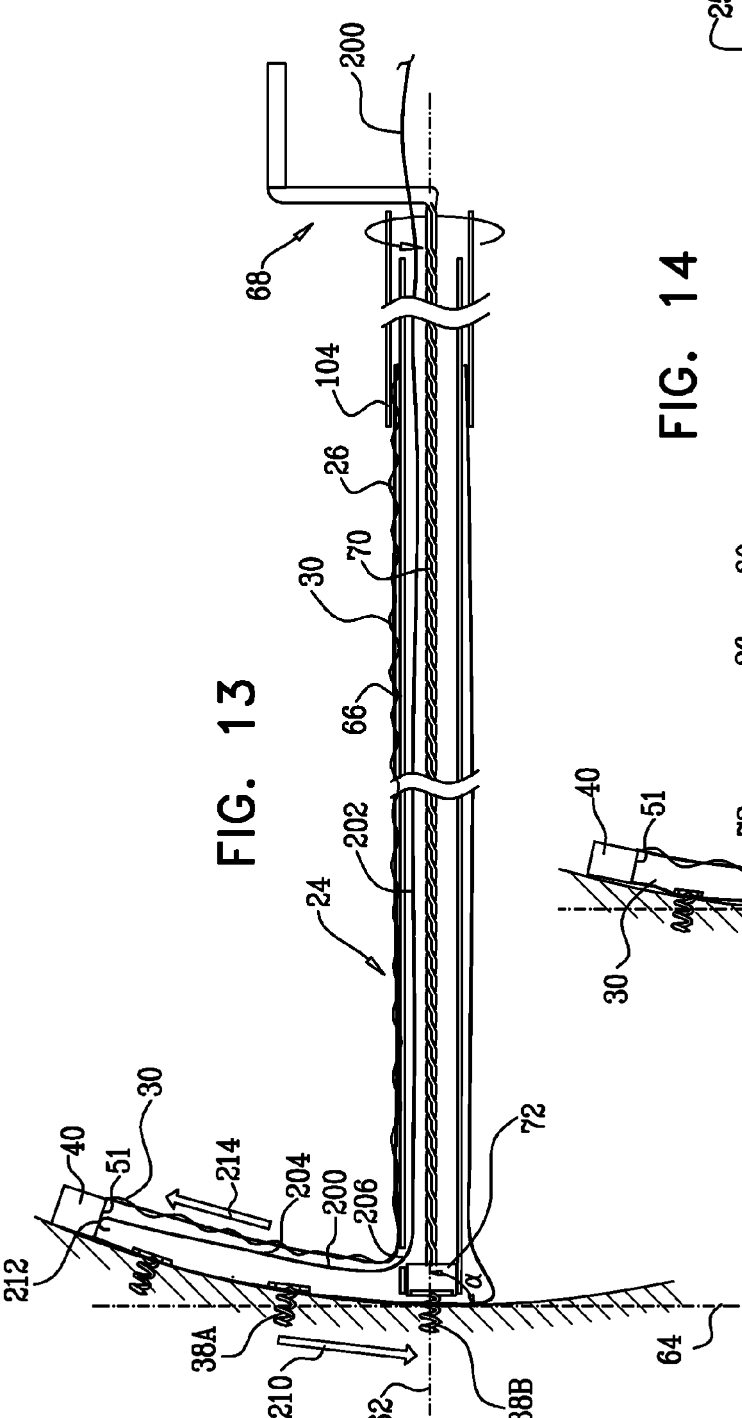
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FIG. 13

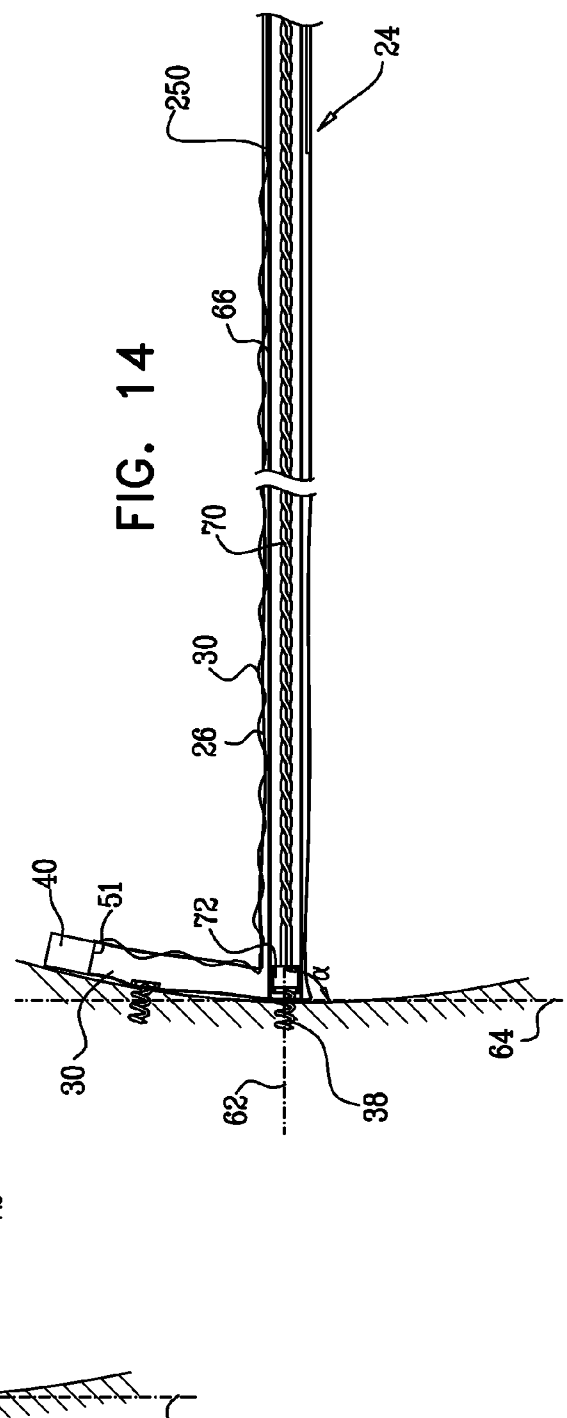
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FIG. 14

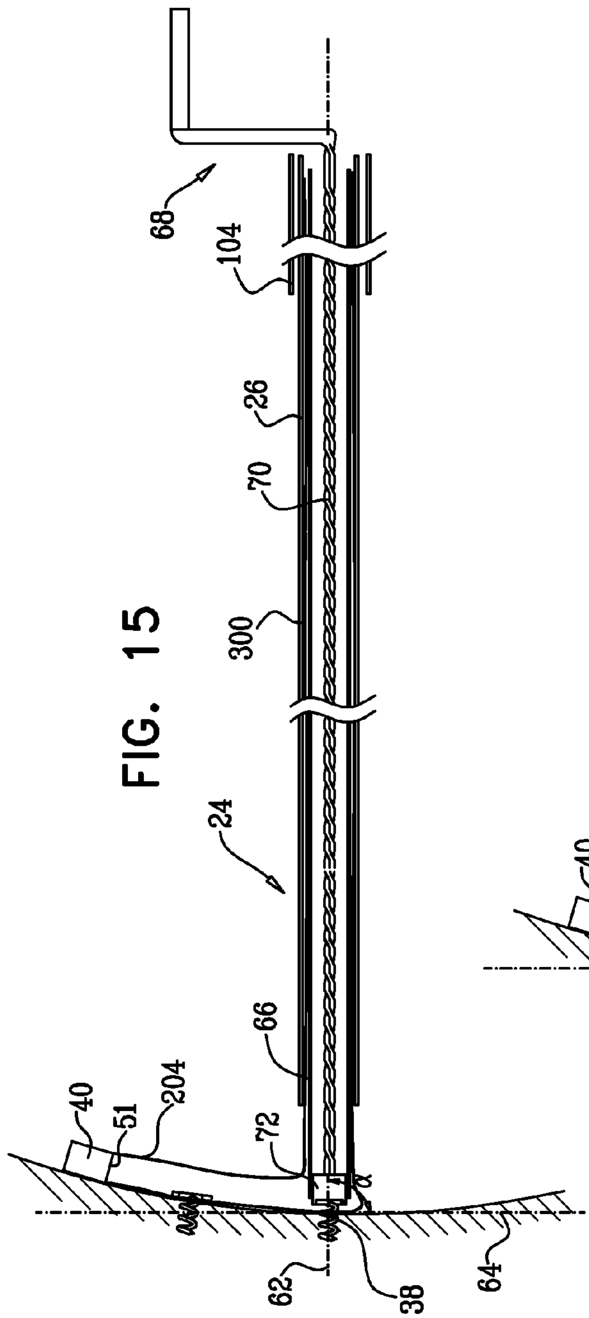
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FIG. 15

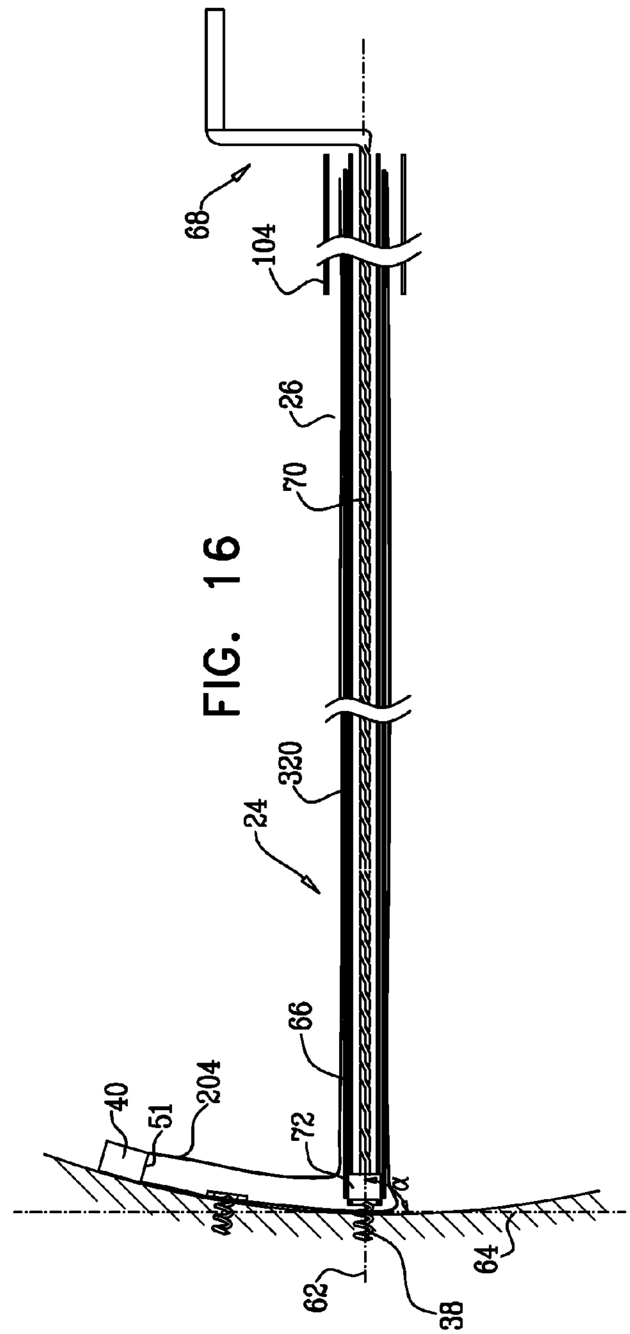
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FIG. 16

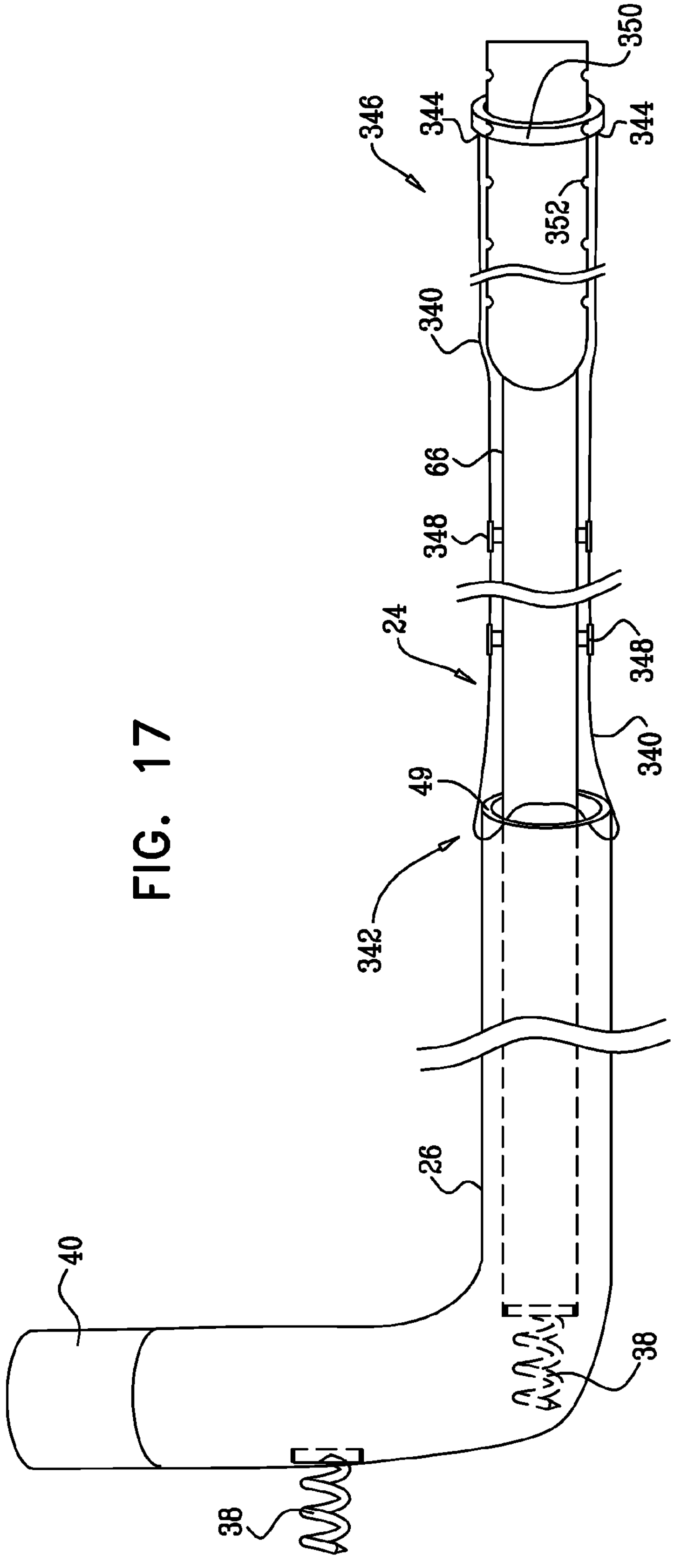

FIG. 17

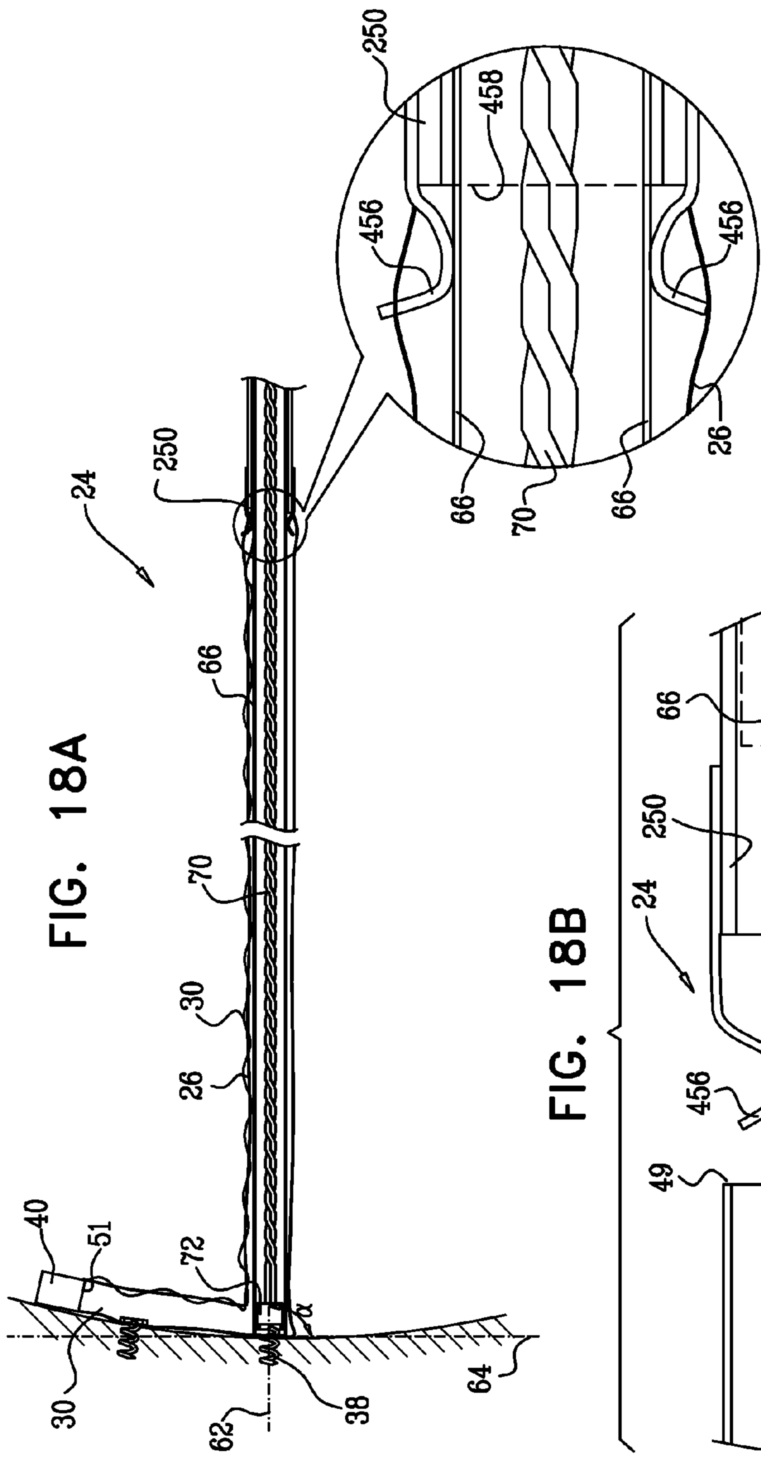

FIG. 18A

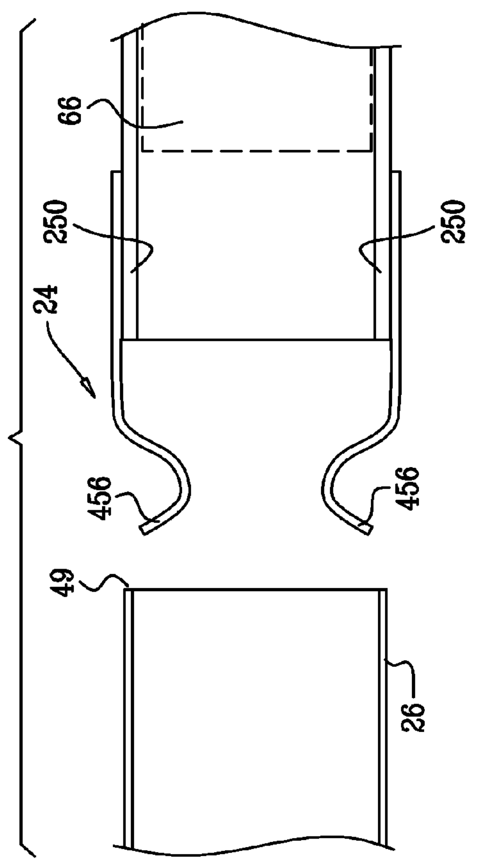

FIG. 18B

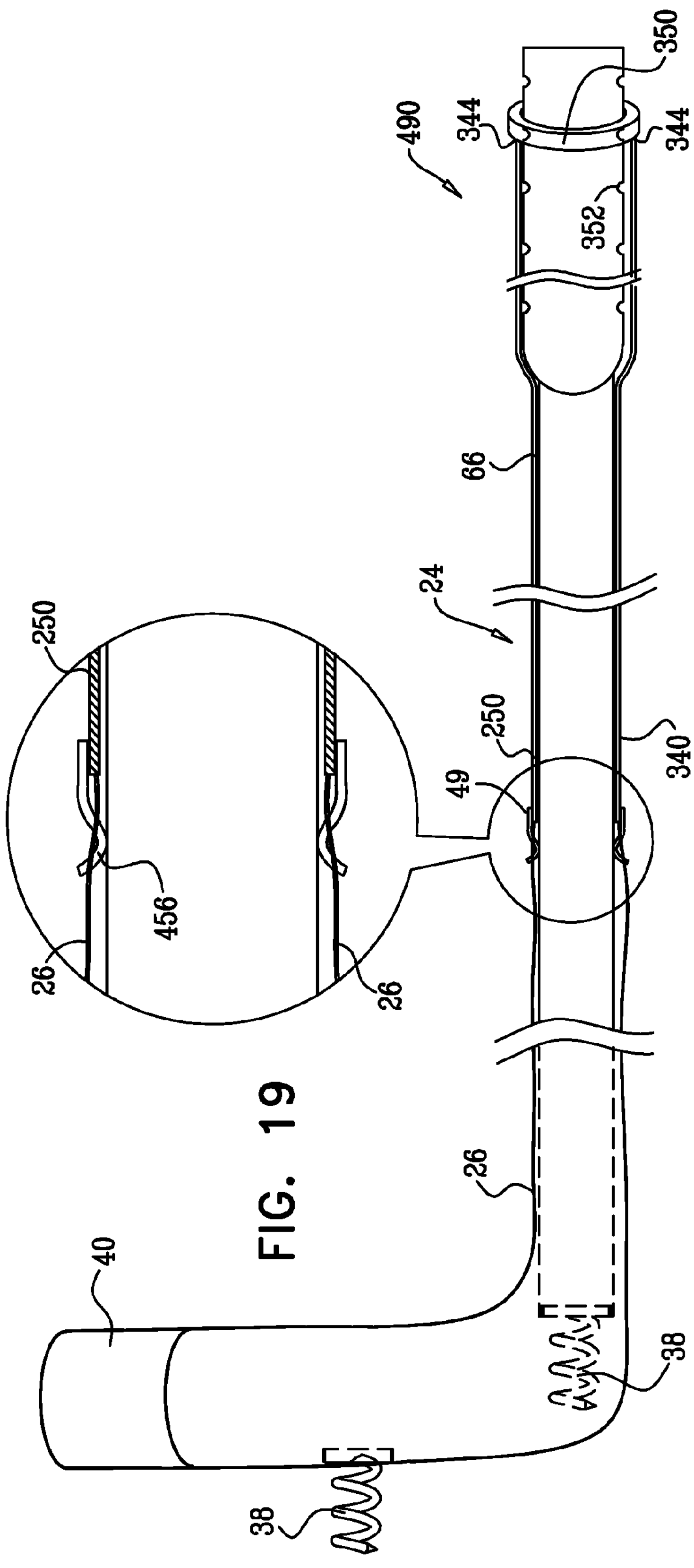

FIG. 19

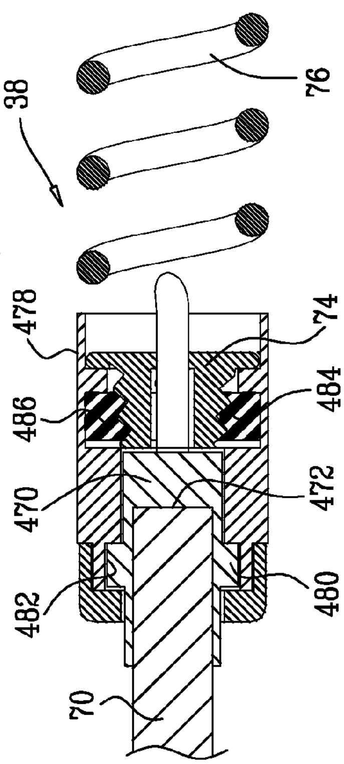

FIG. 20C

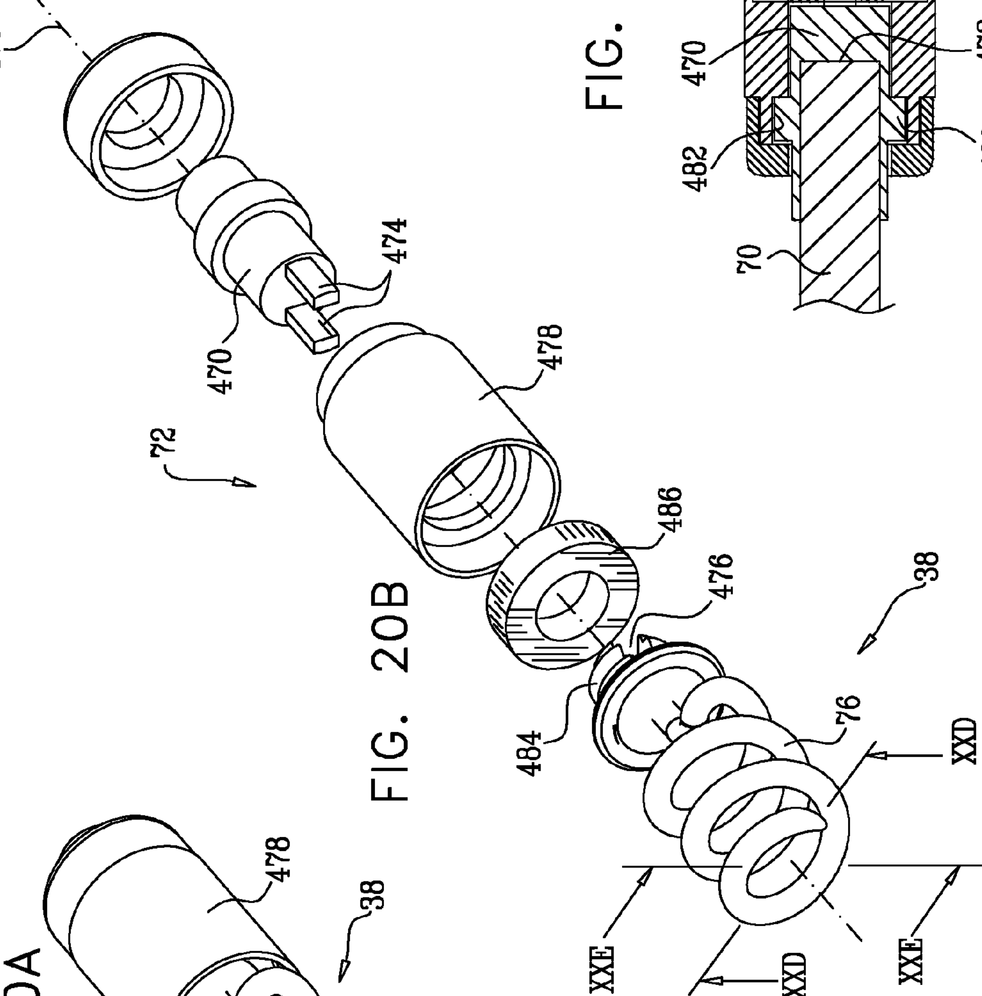

FIG. 20B

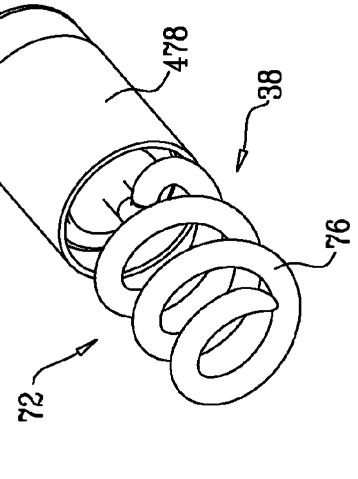

FIG. 20A

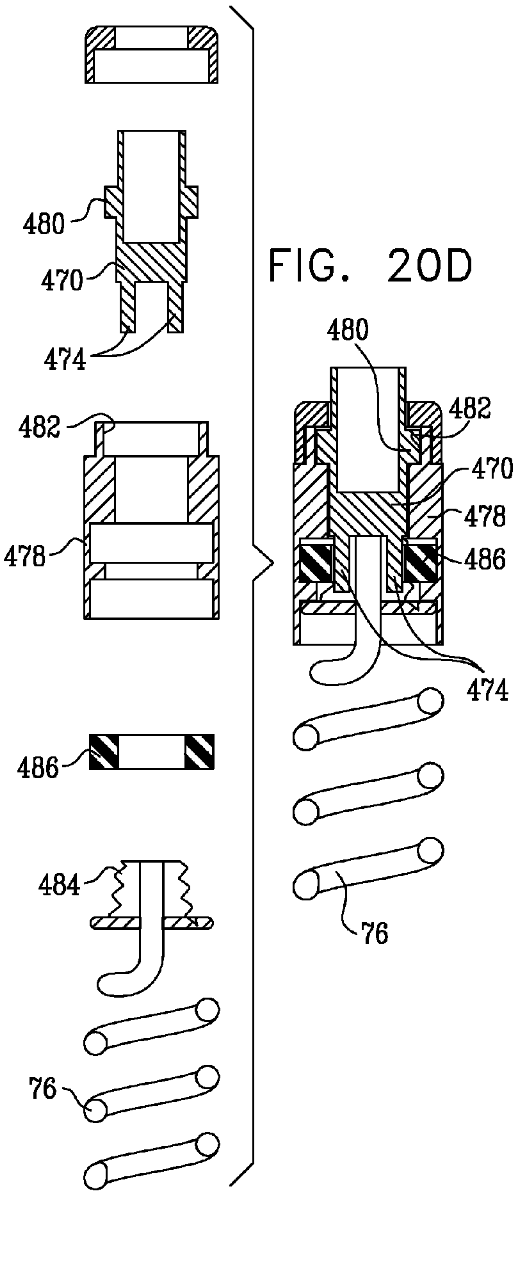

FIG. 20D

FIG. 20E

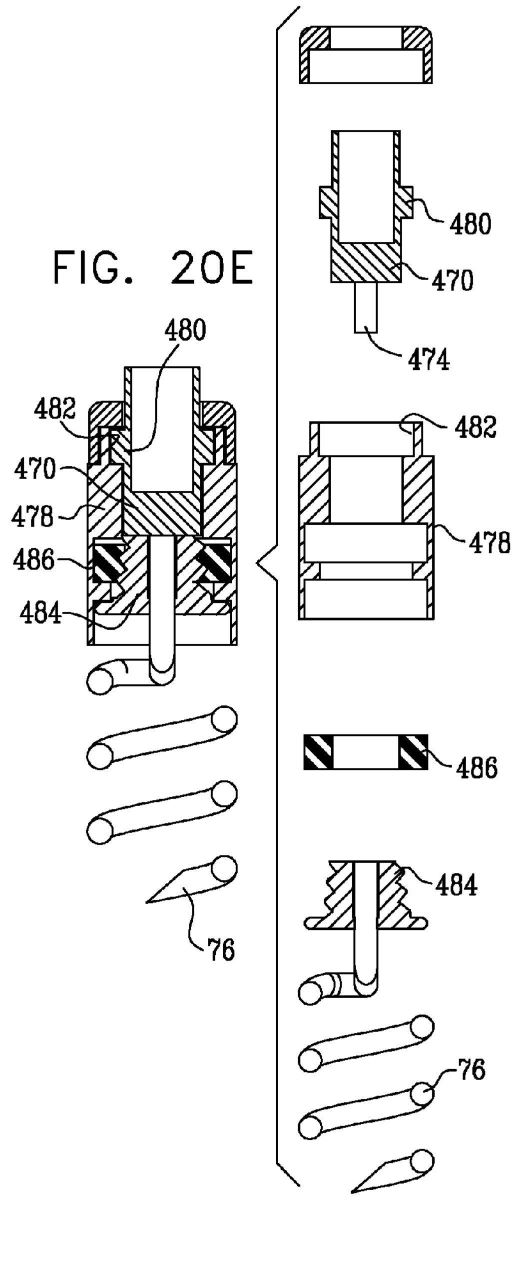

FIG. 21

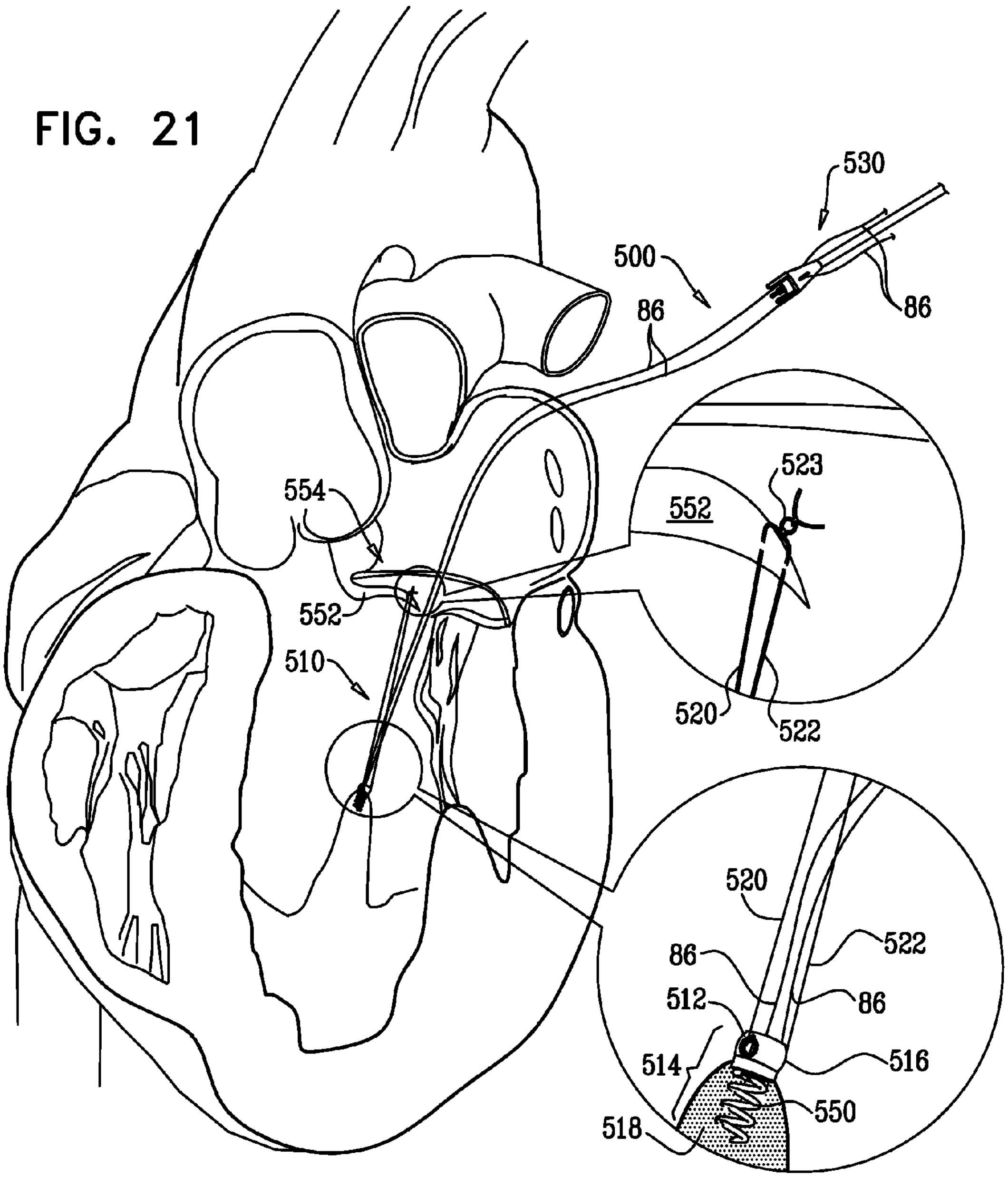
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FIG. 22A

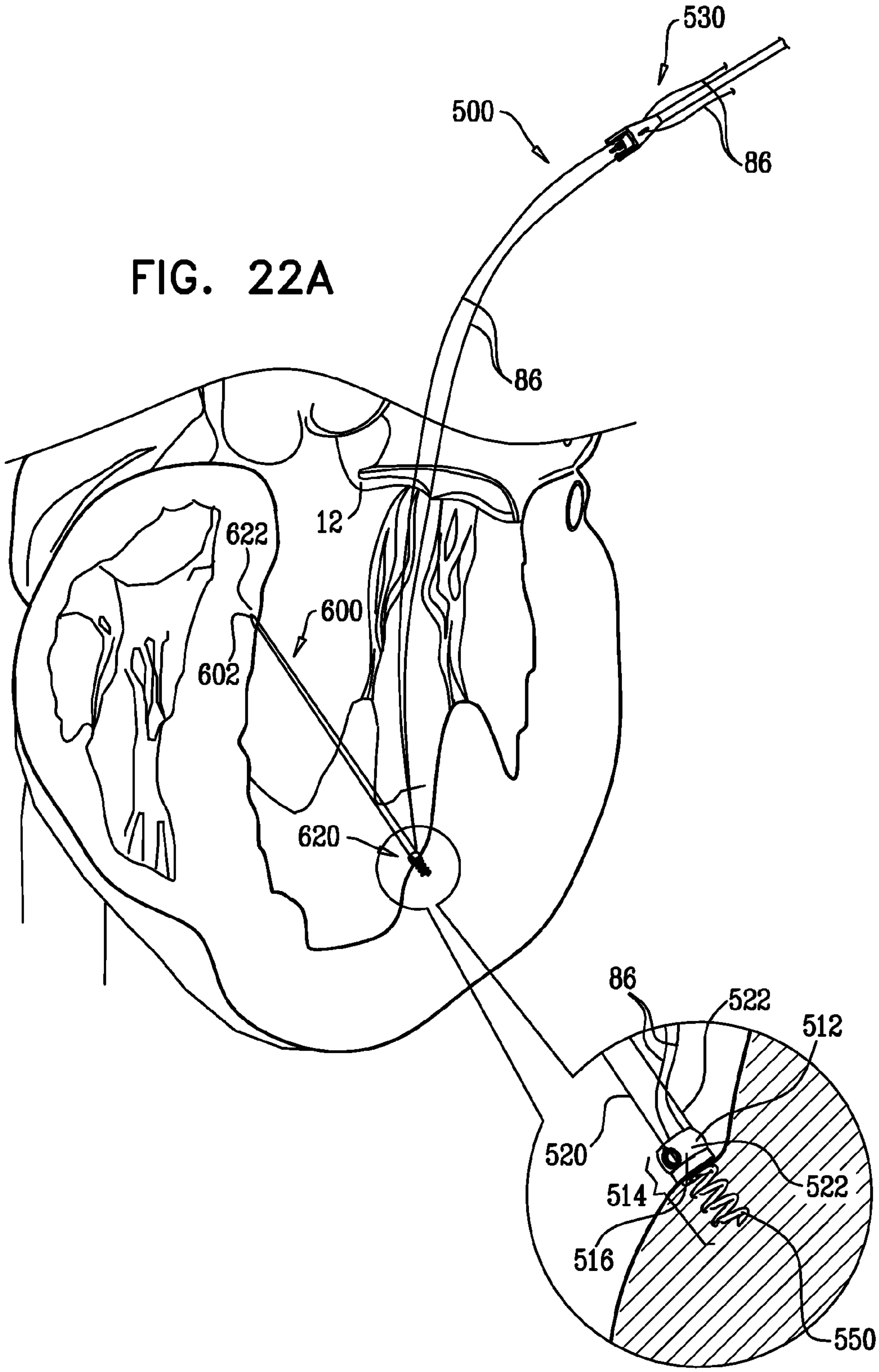
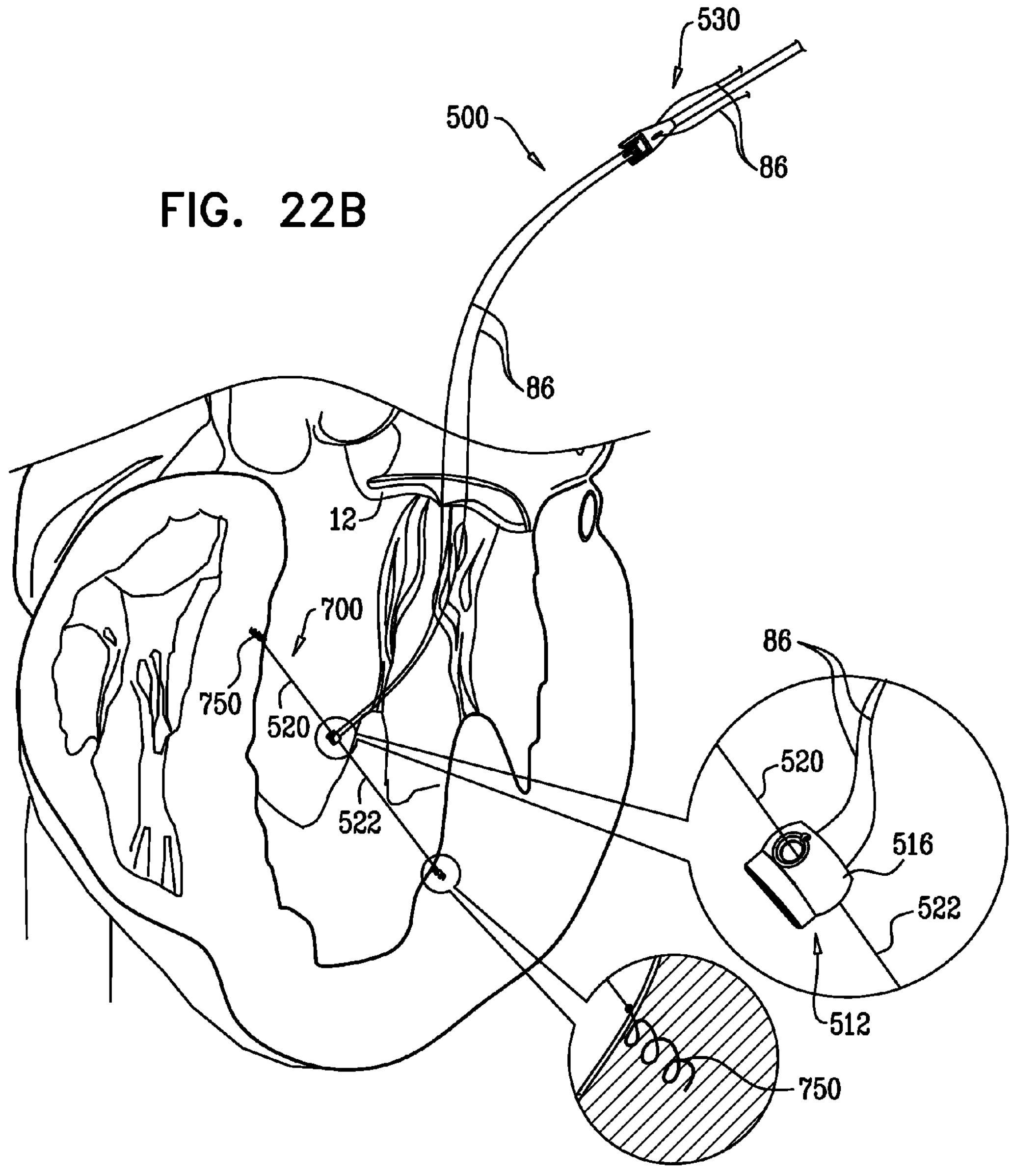


FIG. 22B



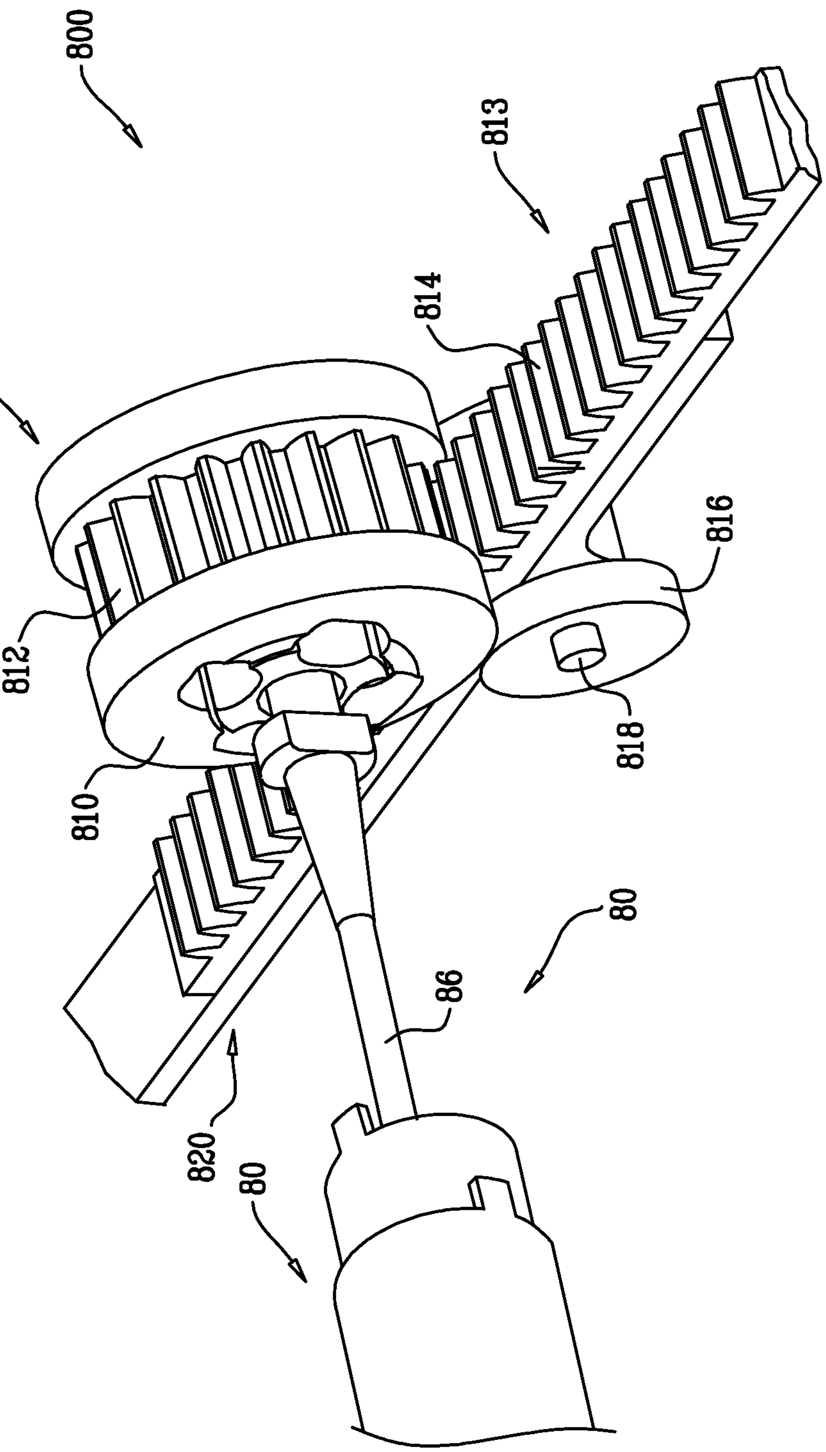


FIG. 23

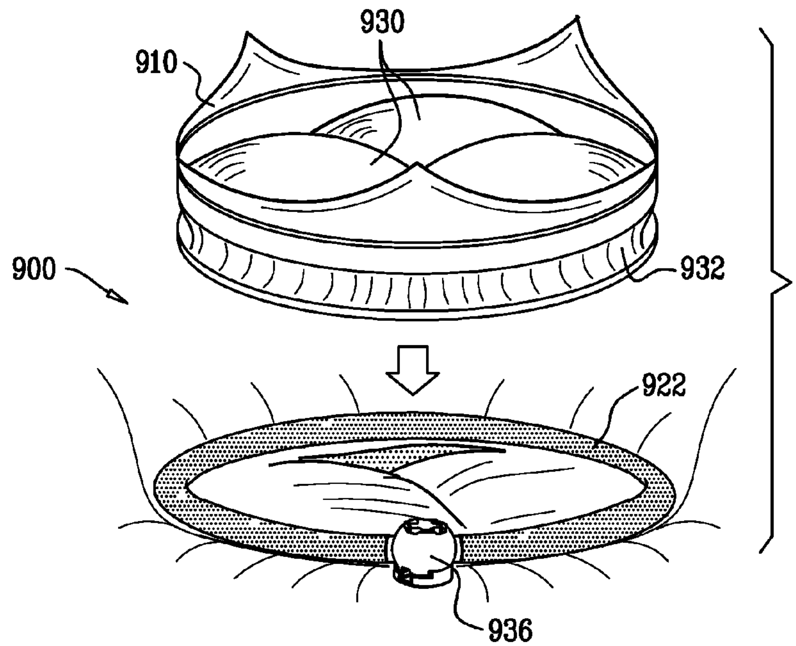


FIG. 24A

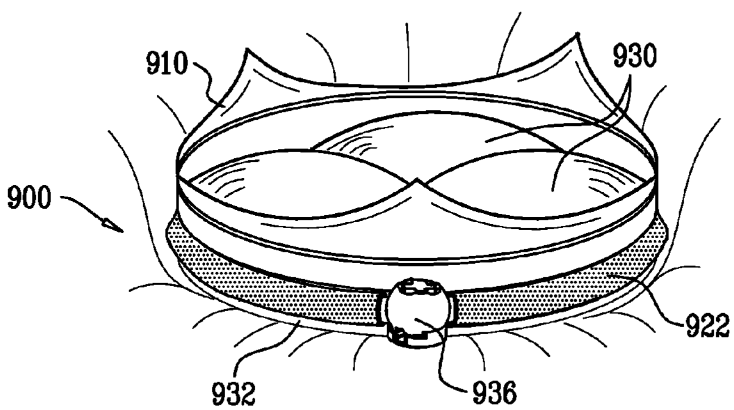


FIG. 24B

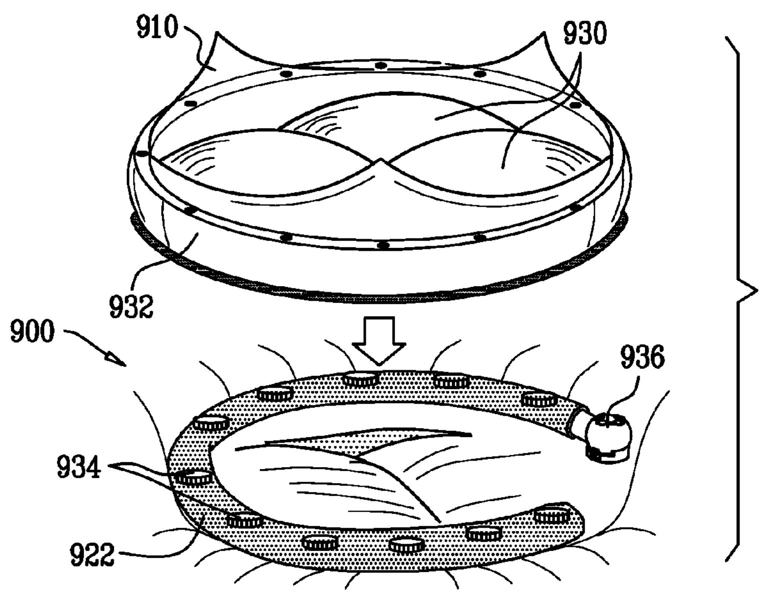


FIG. 25

OVER-WIRE IMPLANT CONTRACTION METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of U.S. patent application Ser. No. 12/689,635, filed Jan. 19, 2010, now U.S. Pat. No. 8,545,553, which is a continuation-in-part of: (a) U.S. patent application Ser. No. 12/435,291, filed May 4, 2009, now U.S. Pat. No. 8,147,542; (b) U.S. patent application Ser. No. 12/437,103, filed May 7, 2009, now U.S. Pat. No. 8,715,342; and (c) U.S. patent application Ser. No. 12/548,991, filed Aug. 27, 2009, now U.S. Pat. No. 8,808,368. The present application is related to U.S. patent application Ser. No. 12/689,693, filed Jan. 19, 2010 on even date herewith, now U.S. Pat. No. 8,911,494. All of the above-mentioned applications are assigned to the assignee of the present application and U.S. patent applications Ser. Nos. 12/435,291, 12/437,103, and 12/548,991 are incorporated herein by reference.

FIELD OF THE APPLICATION

Some embodiments of the present invention relate in general to valve repair, and more specifically to repair of an atrioventricular valve of a patient.

BACKGROUND OF THE APPLICATION

Ischemic heart disease causes mitral regurgitation by the combination of ischemic dysfunction of the papillary muscles, and the dilatation of the left ventricle that is present in ischemic heart disease, with the subsequent displacement of the papillary muscles and the dilatation of the mitral valve annulus.

Dilation of the annulus of the mitral valve prevents the valve leaflets from fully coapting when the valve is closed. Mitral regurgitation of blood from the left ventricle into the left atrium results in increased total stroke volume and decreased cardiac output, and ultimate weakening of the left ventricle secondary to a volume overload and a pressure overload of the left atrium.

US Patent Application Publication 2007/0080188 to Spence et al. describes systems and methods for securing tissue including the annulus of a mitral valve. The systems and methods may employ catheter based techniques and devices to plicate tissue and perform an annuloplasty. Magnets may be used for guidance in deploying fasteners from a catheter. The fasteners are cinched with a flexible tensile member.

U.S. Pat. No. 6,619,291 to Hlavka et al. describes a minimally invasive method of performing annuloplasty. A method for performing a procedure on a mitral valve of a heart includes inserting an implant into a left ventricle and orienting the implant in the left ventricle substantially below the mitral valve. The implant and tissue around the mitral valve are connected and tension is provided to the implant, in one embodiment, in order to substantially reduce an arc length associated with the mitral valve. In another embodiment, the implant is inserted into the left ventricle through the aorta and the aortic valve.

US Patent Application Publication 2006/0241656 to Starksen et al. describes devices, systems and methods for facilitating positioning of a cardiac valve annulus treatment device, thus enhancing treatment of the annulus. Methods generally involve advancing an anchor delivery device

through vasculature of the patient to a location in the heart for treating the valve annulus, contacting the anchor delivery device with a length of the valve annulus, delivering a plurality of coupled anchors from the anchor delivery device to secure the anchors to the annulus, and drawing the anchors together to circumferentially tighten the valve annulus. Devices generally include an elongate catheter having at least one tensioning member and at least one tensioning actuator for deforming a distal portion of the catheter to help it conform to a valve annulus. The catheter device may be used to navigate a subannular space below a mitral valve to facilitate positioning of an anchor delivery device.

US Patent Application Publication 2006/0025787 to Morales et al. describes methods and devices that provide constriction of a heart valve annulus to treat cardiac valve regurgitation and other conditions. Embodiments typically include a device for attaching a cinching or tightening apparatus to a heart valve annulus to reduce the circumference of the annulus, thus reducing valve regurgitation. Tightening devices may include multiple tethered clips, multiple untethered crimping clips, stabilizing devices, visualization devices, and the like. In one embodiment, a plurality of tethered clips is secured circumferentially to a valve annulus, and the tether coupling the clips is cinched to reduce the circumference of at least a portion of the annulus. Methods and devices may be used in open heart surgical procedures, minimally invasive procedures, catheter-based procedures, and/or procedures on beating hearts or stopped hearts.

U.S. Pat. No. 7,431,692 to Zollinger et al. describes an adjustable support pad for adjustably holding a tensioning line used to apply tension to a body organ. The adjustable support pad can include a locking mechanism for preventing slidable movement of the tensioning element in one or both directions. The locking mechanism may include spring-loaded locks, rotatable cam-like structures, and/or rotatable spool structures. The adjustable support pad may be formed from rigid, semi-rigid, and/or flexible materials, and may be formed to conform to the outer surface of a body organ. The adjustable support pad can be configured to adjustably hold one or more separate tensioning lines, and to provide for independent adjustment of one or more tensioning lines or groups thereof.

US Patent Application Publication 2007/0016287 to Cartledge et al. describes an implantable device for controlling shape and/or size of an anatomical structure or lumen. The implantable device has an adjustable member configured to adjust the dimensions of the implantable device. The implantable device is housed in a catheter and insertable from a minimally invasive surgical entry. An adjustment tool actuates the adjustable member and provide for adjustment before, during or after the anatomical structure or lumen resumes near normal to normal physiologic function.

US Patent Application Publication 2004/0236419 to Milo describes methods for reconfiguring an atrioventricular heart valve that may use systems comprising a partial or complete annuloplasty rings proportioned to reconfigure a heart valve that has become in some way incompetent, a pair of trigonal sutures or implantable anchors, and a plurality of staples which may have pairs of legs that are sized and shaped for association with the ring at spaced locations along its length. These systems permit relative axial movement between the staples and the ring, whereby a patient's heart valve can be reconfigured in a manner that does not deter subtle shifting of the native valve components. Shape-memory alloy material staples may have legs with free ends that interlock following implantation. Annuloplasty rings may be complete or partial and may be fenestrated. One alternative method routes a flexible wire, preferably of shape-memory material, through the bights of pre-implanted staples. Other alternative systems use linkers of shape-memory material having hooked ends to interengage with staples or other implanted supports which, following implantation, decrease in effective length and pull the staples or other supports toward one another so as to create desired curvature of the reconfigured valve. These linkers may be separate from the supports or may be integral with them and may have a variety of shapes and forms. Various ones of these systems are described as being implanted non-invasively using a delivery catheter.

US Patent Application Publication 2005/0171601 to Cosgrove et al. describes an annuloplasty repair segment and template for heart valve annulus repair. The elongate flexible template may form a distal part of a holder that also has a proximal handle. Alternatively, the template may be releasably attached to a mandrel that slides within a delivery sheath, the template being released from the end of the sheath to enable manipulation by a surgeon. A tether connecting the template and mandrel may also be provided. The template may be elastic, temperature responsive, or multiple linked segments. The template may be aligned with the handle and form a two- or three-dimensional curve out of alignment with the handle such that the annuloplasty repair segment attached thereto conforms to the curve. The template may be actively or passively converted between its straight and curved positions. The combined holder and ring is especially suited for minimally-invasive surgeries in which the combination is delivered to an implantation site through a small access incision with or without a cannula, or through a catheter passed though the patient's vasculature.

The following patents and patent application publications may be of interest:

U.S. Pat. No. 5,306,296 to Wright et al.
U.S. Pat. No. 5,674,279 to Wright et al.
U.S. Pat. No. 5,961,539 to Northrup, III et al.
U.S. Pat. No. 6,524,338 to Gundry
U.S. Pat. No. 6,569,198 to Wilson et al.
U.S. Pat. No. 6,602,288 to Cosgrove et al.
U.S. Pat. No. 6,602,289 to Colvin et al.
U.S. Pat. No. 6,689,164 to Seguin
U.S. Pat. No. 6,702,826 to Liddicoat et al.
U.S. Pat. No. 6,718,985 to Hlavka et al.
U.S. Pat. No. 6,764,510 to Vidlund et al.
U.S. Pat. No. 7,004,176 to Lau
U.S. Pat. No. 7,101,395 to Tremulis et al.
U.S. Pat. No. 7,175,660 to Cartledge et al.
U.S. Pat. No. 7,186,262 to Saadat

US Patent Application Publication 2002/0087048 to Brock et al.

US Patent Application Publication 2002/0173841 to Ortiz et al.

US Patent Application Publication 2003/0050693 to Quijano et al.

US Patent Application Publication 2003/0167062 to Gambale et al.

US Patent Application Publication 2004/0024451 to Johnson et al.

US Patent Application Publication 2004/0122514 to Fogarty et al.

US Patent Application Publication 2004/0148021 to Cartledge et al.

US Patent Application Publication 2005/0055087 to Starksen

US Patent Application Publication 2005/0288781 to Moaddeb et al.

US Patent Application Publication 2006/0069429 to Spence et al.

US Patent Application Publication 2007/0051377 to Douk et al.

US Patent Application Publication 2007/0055206 to To et al.

US Patent Application Publication 2007/0162111 to Fukamachi et al.

US Patent Application Publication 2007/0255400 to Parravicini et al.

US Patent Application Publication 2008/0004697 to Lichtenstein et al.

PCT Publication WO 01/26586 to Seguin
PCT Publication WO 02/085251 to Hlavka et al.
PCT Publication WO 02/085252 to Hlavka et al.
PCT Publication WO 06/097931 to Gross et al.
PCT Publication WO 07/136783 to Cartledge et al.
PCT Publication WO 08/068756 to Gross et al.

The following articles, all of which are incorporated herein by reference, may be of interest:

O'Reilly S et al., "Heart valve surgery pushes the envelope," Medtech Insight 8(3): 73, 99-108 (2006)

Dieter R S, "Percutaneous valve repair: Update on mitral regurgitation and endovascular approaches to the mitral valve," Applications in Imaging, Cardiac Interventions, Supported by an educational grant from Amersham Health pp. 11-14 (2003)

Swain C P et al., "An endoscopically deliverable tissue-transfixing device for securing biosensors in the gastrointestinal tract," Gastrointestinal Endoscopy 40(6): 730-734 (1994)

Odell J A et al., "Early Results of a Simplified Method of Mitral Valve Annuloplasty," Circulation 92:150-154 (1995)

SUMMARY

In some embodiments of the present invention, an implant structure is provided that comprises a contracting mechanism. The contracting mechanism comprises a rotatable structure, arranged such that rotation of the rotatable structure contracts the implant structure. The implant further comprises a longitudinal member, such as a wire, which is coupled to the contracting mechanism. A rotation tool is provided for rotating the rotatable structure. The tool is configured to be guided along (e.g., over, alongside, or through) the longitudinal member, to engage the rotatable structure, and to rotate the rotatable structure in response to a rotational force applied to the tool.

In some embodiments of the present invention, the implant structure comprises an adjustable partial annuloplasty ring for repairing a dilated valve annulus of an atrioventricular valve, such as a mitral valve. The annuloplasty ring comprises a flexible sleeve and a plurality of anchors. An anchor deployment manipulator is advanced into a lumen of the sleeve, and, from within the lumen, deploys the anchors through a wall of the sleeve and into cardiac tissue, thereby anchoring the sleeve around a portion of the valve annulus.

In some embodiments of the present invention, the anchor deployment manipulator comprises a steerable outer tube in which is positioned an anchor driver having an elongated, flexible shaft. Rotation of the anchor driver screws the anchors into the cardiac tissue. The anchors may, for example, be helical in shape.

For some applications, the annuloplasty ring is typically configured to be placed only partially around the valve annulus (e.g., to assume a C-shape), and, once anchored in place, to be contracted so as to circumferentially tighten the valve annulus. To this end, the annuloplasty ring may comprise a flexible contracting member such as a wire, which is typically positioned within the lumen of the sleeve.

For some applications, the contracting mechanism comprises a spool to which a first end of the contracting member is coupled. Rotation of the spool winds a portion of the contracting member around the spool, thereby contracting the implant structure. For some applications, the contracting mechanism comprises a housing that houses the spool, and the rotation tool is configured to engage and rotate the spool with respect to the housing. For some applications, the rotation tool comprises a tube, which is configured to be passed over the longitudinal member coupled to the contracting mechanism, and to engage the housing, such that the housing is held rotationally stationary when the tube is held rotationally stationary.

For some applications, the longitudinal member is removably coupled to the contracting mechanism, e.g., to the rotatable structure of the contracting mechanism. For example, a distal portion of the longitudinal member may be shaped so as to define a screw thread, and the contracting mechanism may shaped so as to define a threaded opening, into which the distal portion of the longitudinal member is screwed so as to removably couple the longitudinal member to the contracting mechanism.

For some applications, the rotation tool comprises a first tube, which is configured to pass over the longitudinal member. Rotation of the tube decouples the longitudinal member from the contracting mechanism. For some applications, the rotation tool further comprises a second tube, which is configured to pass over the first tube. The second tube engages the rotatable structure, such that rotation of the second tube rotates the rotatable structure.

In some embodiments of the present invention, a rotation handle is provided. A longitudinal member, such as the proximal end of the longitudinal member coupled to the contracting mechanism, is passed at least partially through the rotation handle. The rotation handle comprises (a) a first-tube rotation knob, which is coupled to the first tube, such that rotation of the first-tube rotation knob rotates the first tube, (b) a second-tube rotation knob, which is coupled to the second tube, such that rotation of the second-tube rotation knob rotates the second tube, and (c) a control knob. When in a first position, the control knob engages both first-tube and second-tube rotation knobs. When in a second position, the control knob engages the second-tube rotation knob but not the first-tube rotation knob. For some applications, when in the first position, the control knob at least partially (typically entirely) covers the first-tube tube rotation knob, thereby preventing access to the knob by the surgeon. When in the second position, the control knob reveals (i.e., no longer covers) the first-tube tube rotation knob. The surgeon thus has convenient access to the exposed knob.

For some application in which the implant structure comprises an annuloplasty ring, all of the tools and elements of the annuloplasty system that are introduced into left atrium are contained within the sleeve of the annuloplasty ring, which reduces the risk that any elements of the system will accidentally be released to the blood circulation, or damage surrounding tissue. In addition, the lumen of the sleeve provides guidance if it should be necessary to return to a previously deployed anchor, such as to tighten, loosen, remove, or relocate the anchor. For some applications, the anchors comprise helical screws, which facilitate such adjusting or removing.

The annuloplasty ring may be advanced toward the annulus of a valve in any suitable procedure, e.g., a transcatheter procedure, a percutaneous procedure, a minimally invasive procedure, or an open heart procedure.

There is therefore provided, in accordance with an application of the present invention, apparatus including:

an implant structure, which includes a contracting mechanism, which includes a rotatable structure, arranged such that rotation of the rotatable structure contracts the implant structure;

a longitudinal member, which is coupled to the contracting mechanism; and

a tool for rotating the rotatable structure, the tool configured to be guided along the longitudinal member, to engage the rotatable structure, and to rotate the rotatable structure in response to a rotational force applied to the tool.

For some applications, the longitudinal member includes at least one wire, and the tool is configured to be guided over the wire. For other applications, the longitudinal member includes a tube, and the tool is configured to be guided through the tube.

For some applications, the implant structure includes an annuloplasty ring. Alternatively, the implant structure includes at least one repair chord, which is configured to pull two portions of heart tissue toward each other upon contraction of the implant structure.

For some applications, the implant structure includes one or more tissue anchors.

For some applications, a portion of the implant structure is shaped so as to define a rack, a portion of the rotatable structure is shaped so as to define a pinion that mates with the rack, and the implant structure is configured such that rotation of the rotatable structure causes the portion of the implant structure to move with respect to the rotatable structure.

For some applications, the implant structure includes a flexible contracting member that is coupled to the rotatable structure, and arranged such that rotation of the rotatable structure tightens the flexible contracting member, thereby contracting the implant structure.

For some applications, the rotatable structure includes a spool, the implant structure is coupled to the spool, and arranged such that rotation of the spool winds a portion of the implant structure around the spool, and the tool is configured to engage and rotate the spool. For some applications, the implant structure includes a flexible contracting member that is coupled to the spool, the portion of the implant structure includes a portion of the contracting member, and the contracting member is arranged such that rotation of the spool winds the portion of the contracting member around the spool.

For some applications, the contracting mechanism includes a housing that houses the spool, and the tool is configured to engage and rotate the spool with respect to the housing. For some applications, the tool includes a tube, which is configured to be passed over the longitudinal member and to engage the housing, such that the housing is held rotationally stationary when the tube is held rotationally stationary.

For some applications, the longitudinal member is removably coupled to the contracting mechanism. For some applications, a distal portion of the longitudinal member is shaped so as to define a screw thread, and the contracting mechanism is shaped so as to define a threaded opening, into which the distal portion of the longitudinal member is screwed so as to removably couple the longitudinal member to the contracting mechanism. For some applications, the longitudinal member is removably coupled to the rotatable structure of the contracting mechanism. For some applications, the tool includes a tube, which is configured to pass over the longitudinal member, and which is configured such that rotation of the tube decouples the longitudinal member from the contracting mechanism.

For some applications, the tube is a first tube, the tool further includes a second tube, the first tube is positioned within the second tube, and the second tube is configured to engage the rotatable structure, such that rotation of the second tube rotates the rotatable structure. For some applications, the apparatus further includes a rotation handle, through which a proximal end of the longitudinal member at least partially passes, and which includes: a first-tube rotation knob, which is coupled to the first tube, such that rotation of the first-tube rotation knob rotates the first tube; a second-tube rotation knob, which is coupled to the second tube, such that rotation of the second-tube rotation knob rotates the second tube; and a control knob, which, when in a first position, engages both first-tube and second-tube rotation knobs, and when in a second position, engages the second-tube rotation knob but not the first-tube rotation knob. For some applications, the rotation handle includes a handle housing, and the control knob, when in the second position, engages the handle housing, thereby rotationally fixing the control knob to the handle housing.

For some applications, the tool further includes a third tube, the first and second tubes are positioned within the third tube, the rotatable structure includes a spool, the contracting mechanism includes a housing that houses the spool, the implant structure is coupled to the spool, and arranged such that rotation of the spool winds a portion of the implant structure around the spool, and the second tube is configured to engage and rotate the spool with respect to the housing, and the third tube is configured to engage the housing, such that the housing is held rotationally stationary when the third tube is held rotationally stationary.

For some applications, the contracting mechanism includes a locking mechanism, the longitudinal member is shaped so as to define a distal force applicator, which is configured to unlock the locking mechanism when the longitudinal member is coupled to the contracting mechanism, thereby allowing the spool to rotate with respect to the housing.

There is further provided, in accordance with an application of the present invention, apparatus including:

a longitudinal member;

a first tube, which passes over the longitudinal member;

a second tube, which passes over the first tube; and

a rotation handle, through which the longitudinal member at least partially passes, and which includes:

- a first-tube rotation knob, which is coupled to the first tube, such that rotation of the first-tube rotation knob rotates the first tube;
- a second-tube rotation knob, which is coupled to the second tube, such that rotation of the second-tube rotation knob rotates the second tube; and
- a control knob, which:
  - when in a first position, engages both the first-tube and second-tube rotation knobs, and
  - when in a second position, engages the second-tube rotation knob but not the first-tube rotation knob.

For some applications, the longitudinal member includes at least one wire.

For some applications, the rotation handle is configured such that the rotation of the control knob, (a) when in the first position, rotates both the first-tube and second-tube rotation knobs, and (b) when in the second position, rotates the second-tube rotation knob but not the first-tube rotation knob.

For some applications, the rotation handle is configured such that the control knob, (a) when in the first position, at least partially covers the first-tube rotation knob, thereby preventing access to the first-tube rotation knob, and (b) when in the second position, reveals the first-tube rotation knob, thereby allowing access to the first-tube rotation knob. For some applications, the control knob is configured to slide between the first and second positions.

For some applications, the control knob is configured such that a transition between the first and second positions is not effected by rotation of the control knob.

For some applications, the control knob is configured to slide between the first and second positions. For some applications, the control knob is configured such that when in the first position, an inner surface of the control knob engages the first-tube rotation knob and the second-tube rotation knob. For some applications, the rotation handle includes a handle housing, and the sliding control knob, when in the second position, engages the handle housing, thereby rotationally fixing the control knob to the handle housing. For some applications, the control knob is configured that when in the second position, an outer surface of the control knob engages the handle housing.

For some applications, the apparatus further includes a third tube, which passes over the second tube, and which is coupled to the rotation handle such that the third tube cannot rotate with respect to the rotation handle.

For some applications, the first and second tubes extend from a distal end of the rotation handle, and the rotation handle includes one or more springs which are configured to push at least one of the first and second tubes in a distal direction. For some applications, the rotation handle includes a spring locking mechanism, which is configured to assume locking and released states, and, when in the locking state, to prevent at least one of the springs from pushing on at least one of the first and second tubes in the distal direction.

For some applications, the longitudinal member is longitudinally fixed to the rotation handle, but is allowed to rotate with respect to the rotation handle. For some applications, the first and second tubes extend from a distal end of the rotation handle, and the rotation handle includes a lever that is configured to allow the longitudinal member to be advanced toward a proximal end of the rotation handle, while preventing withdrawal of the longitudinal member toward the distal end of the rotation handle.

For some applications, the apparatus further includes an implant structure, which includes a contracting mechanism, which includes a rotatable structure, arranged such that rotation of the rotatable structure contracts the implant structure, the longitudinal member is removably coupled to the contracting mechanism, the first tube is configured such that rotation of the tube decouples the longitudinal member from the contracting mechanism, and the second tube is configured to engage the rotatable structure, such that rotation of the second tube rotates the rotatable structure.

There is still further provided, in accordance with an application of the present invention, apparatus including:

a sleeve having a lumen;

a deployment manipulator tube, which is configured to be removably positioned partially within the lumen of the sleeve, such that the deployment manipulator tube extends out of a proximal end of the sleeve; and

a pusher tube, which is configured to pass over a portion of the deployment manipulator tube, such that a distal end of the pusher tube is in contact with the proximal end of the sleeve.

For some applications, the apparatus further includes an annuloplasty ring, which includes the sleeve. For some applications, the annuloplasty ring further includes at least one tissue anchor. For some applications, the annuloplasty ring includes a partial annuloplasty ring.

For some applications, the distal end of the pusher tube is removably coupled to the proximal end of the sleeve. For some applications, the pusher tube includes one or more coupling elements, which are configured to removably couple the distal end of the pusher tube to the proximal end of the sleeve. For some applications, the apparatus is configured such that (a) when the deployment manipulator tube is positioned within the lumen of the sleeve, the deployment manipulator tube causes the coupling elements to engage the sleeve, thereby removably coupling the distal end of the pusher tube to the proximal end of the sleeve, and (b) when the deployment manipulator tube is withdrawn from the sleeve, the coupling elements disengage from the sleeve, thereby decoupling the distal end of the pusher tube from the proximal end of the sleeve. For some applications, the coupling elements are configured to have a natural tendency to flex inwards toward a central longitudinal axis of the sleeve that passes through the proximal end of the sleeve, and the deployment manipulator tube, when positioned within the lumen of the sleeve, pushes the coupling elements outwards away from the longitudinal axis, thereby causing the coupling elements to engage the sleeve.

For some applications, the apparatus further includes an external control handle, which is coupled to a proximal portion of the deployment manipulator tube and to a proximal end of the pusher tube, and which is configured to controllably release the pusher tube in a distal direction as the sleeve is withdrawn from the deployment manipulator tube. For some applications, the external control handle is configured to controllably release the pusher tube incrementally in the distal direction by one or more set distances.

For some applications, the annuloplasty system further includes: at least one tissue anchor; and an anchor deployment manipulator, which includes: the deployment manipulator tube; and an anchor driver, which is configured to be at least partially positioned within the deployment manipulator tube, and, while so positioned, to deploy the at least one anchor through a wall of the sleeve.

There is additionally provided, in accordance with an application of the present invention, apparatus for use with tissue of a subject, the apparatus including:

an anchor driver, which includes a driver head, which is shaped so as to define one or more mechanical coupling elements, and which includes a flexible ring; and

an anchor, which includes:

a coupling head, which is shaped so as to define: (a) one or more mating elements corresponding to the mechanical coupling elements, and configured to engage the mechanical coupling elements such that rotation of the mechanical coupling elements rotates the mating elements, which in turn rotate the coupling head, and (b) an outer coupling surface, sized to be inserted into and engage the flexible ring; and

a tissue coupling element, which is fixed to the coupling head,

wherein the rotation of the mechanical coupling elements causes the tissue coupling element of the anchor to screw itself into the tissue, thereby causing separation of: (a) the outer coupling surface of the coupling head from the flexible ring, and (b) the mating elements of the coupling head from the corresponding mechanical coupling elements.

For some applications, the driver head includes: an inner mating component, which is shaped so as to define the one or more mechanical coupling elements; and an outer element, which at least partially surrounds the inner mating component and extends in a distal direction beyond a distal end of the inner mating component, and the flexible ring is coupled to an inner surface of the outer element. For some applications, the outer element is configured to rotate freely with respect to the inner mating component.

For some applications, the coupling surface of the coupling head is shaped so as to define a screw thread, such that rotation of the mechanical coupling elements causes the outer coupling surface to unscrew from the flexible ring.

For some applications, the mechanical coupling elements of the driver head include protrusions, and the mating elements of the coupling head include slots.

For some applications, the anchor driver further includes a shaft, and the driver head is coupled to a distal end of the shaft. For some applications, the inner mating component is coupled to the distal end of the shaft such that the inner mating component is rotationally fixed to the shaft.

For some applications, the apparatus further includes an annuloplasty ring, which includes a sleeve having a lumen, and the anchor driver is configured to be removably positioned within the lumen of the sleeve.

For some applications, the coupling element is shaped so as to define a shape selected from the group consisting of: a helix, a spiral, and a screw shaft.

There is yet additionally provided, in accordance with an application of the present invention, a method including:

placing, into a body of a subject, an implant structure, which includes a contracting mechanism that includes a rotatable structure, such that a longitudinal member coupled to the contracting mechanism extends outside of the body;

guiding a tool along the longitudinal member to the rotatable structure;

engaging the rotatable structure with the tool; and

contracting the implant structure by rotating the rotatable structure using the tool.

For some applications, the longitudinal member includes at least one wire, and guiding the tool includes guiding the tool over the wire.

For some applications, the longitudinal includes at least one tube, and guiding the tool includes guiding the tool through the tube.

For some applications, placing the implant structure includes placing an annuloplasty ring into an atrium of the body in a vicinity of an annulus of an atrioventricular valve.

For some applications, placing the implant structure includes placing at least one repair chord into a ventricle of the body such that, upon contracting of the implant structure, the repair chord pulls two portions of heart tissue toward each other.

For some applications, a portion of the implant structure is shaped so as to define a rack, a portion of the rotatable structure is shaped so as to define a pinion that mates with the rack, and contracting the implant structure includes moving the portion of the implant structure with respect to the rotatable structure by rotating the rotatable structure using the tool.

For some applications, the implant structure includes a flexible contracting member that is coupled to the rotatable structure, and contracting the implant structure includes tightening the flexible contracting member by rotating the rotatable structure using the tool.

For some applications, the rotatable structure includes a spool, the implant structure is coupled to the spool, engaging includes engaging the spool with the tool, and contracting the implant structure includes winding a portion of the implant structure around the spool by rotating the spool using the tool. For some applications, the implant structure includes a flexible contracting member that is coupled to the spool, the portion of the implant structure includes a portion of the contracting member, and winding includes winding the portion of the contracting member around the spool by rotating the spool using the tool.

For some applications, the contracting mechanism including a housing that houses the spool, and winding includes winding includes rotating the spool with respect to the housing. For some applications, the tool includes a tube, and guiding the tool over the longitudinal member includes passing the tube over the longitudinal member and engaging the housing with the tube such that the housing is held rotationally stationary when the tube is held rotationally stationary.

For some applications, the method further includes decoupling the longitudinal member from the contracting mechanism after rotating the rotatable structure. For some applications, a distal portion of the longitudinal member is shaped so as to define a screw thread, the contracting mechanism is shaped so as to define a threaded opening, into which the distal portion of the longitudinal member is initially screwed, and decoupling includes unscrewing the longitudinal member from the threaded opening. For some applications, the longitudinal member is removably coupled to the rotatable structure of the contracting mechanism, and decoupling includes decoupling the longitudinal member from the rotatable structure.

For some applications, the tool includes a tube, guiding the tool over the longitudinal member includes passing the tube over the longitudinal member, and decoupling the longitudinal member from the contracting mechanism includes rotating the tube. For some applications, the tube is a first tube, rotating the tube includes rotating the first tube, the tool further includes a second tube, the first tube is positioned within the second tube, engaging includes engaging the rotatable structure with the second tube, and contracting the implant structure includes rotating the rotatable structure by rotating the second tube. For some applications, the method further includes passing a proximal end of the longitudinal member at least partially through a rotation handle, which includes a first-tube rotation knob coupled to the first tube, a second tube-rotation knob coupled to the second tube, and a control knob, which (a) when in a first position, engages both the first-tube and second-tube rotation knobs, and (b) when in a second position, engages the second-tube rotation knob but not the first-tube rotation knob, and engages a housing of the handle, thereby rotationally fixing the control knob to the handle housing, contracting the implant structure includes rotating the first and second tubes by rotating the control knob when in the first position, and decoupling the longitudinal member from the contracting mechanism includes moving the control knob into the second position, and subsequently rotating the first tube by rotating the first-tube rotation knob.

For some applications, the tool further includes a third tube, the first and second tubes are positioned within the third tube, the rotatable structure includes a spool, the contracting mechanism includes a housing that houses the spool, the implant structure is coupled to the spool, and contracting the implant includes: rotating a portion of the implant structure around the spool by rotating the spool with respect to the housing by rotating the second tube; engaging the housing with the third tube; and holding the housing rotationally stationary by holding the third tube rotationally stationary.

For some applications, the contracting mechanism includes a locking mechanism, and the longitudinal member is shaped so as to define a distal force applicator, which is configured to unlock the locking mechanism when the longitudinal member is coupled to the contracting mechanism, thereby allowing the spool to rotate with respect to the housing.

There is also provided, in accordance with an application of the present invention, a method including:

passing a longitudinal member at least partially through a rotation handle, which includes (a) a first-tube rotation knob, which is coupled to a first tube that passes over the longitudinal member, (b) a second-tube rotation knob, which is coupled to a second tube that passes over the first tube, and (c) a control knob, which (i) when in a first position, engages both the first-tube and second-tube rotation knobs, and (ii) when in a second position, engages the second-tube rotation knob but not the first-tube rotation knob, and engages a housing of the handle, thereby rotationally fixing the control knob to the handle housing;

rotating the first and second tubes by rotating the control knob when in the first position; and

moving the control knob into the second position, and subsequently rotating the first tube by rotating the first-tube rotation knob.

For some applications, the longitudinal includes at least one wire, and passing includes passing the wire at least partially through the rotation handle.

For some applications, moving the control knob into the second position does not include rotating the control knob.

For some applications, moving the control knob into the second position includes sliding the control knob into the second position.

For some applications, passing the longitudinal member at least partially through the rotation handle includes longitudinally fixing the longitudinal member to the rotation handle such that the longitudinal member is allowed to rotate with respect to the rotation handle.

For some applications, the method further includes:

placing, into a body of a subject, an implant structure, which includes a contracting mechanism that includes a rotatable structure, arranged such that rotation of the rotatable structure contracts the implant structure, wherein the longitudinal member is removably coupled to the contracting mechanism;

engaging the rotatable structure with the second tube such that rotation of the second tube rotates the rotatable structure; and

engaging the longitudinal member with the first tube, such that rotation of the first tube decouples the longitudinal member from the contracting mechanism.

There is further provided, in accordance with an application of the present invention, a method including:

removably positioning a deployment manipulator tube partially within a lumen of a sleeve of an annuloplasty ring, such that the deployment manipulator tube extends out of a proximal end of the sleeve; and placing a pusher tube over the deployment manipulator tube such that a distal end of the pusher tube is in contact with the proximal end of the sleeve.

For some applications, the method further includes withdrawing the sleeve from the deployment manipulator tube in a distal direction, and, while withdrawing, pushing the pusher tube against the proximal end of the sleeve. For some applications, withdrawing the sleeve includes, while withdrawing the sleeve, controllably releasing the pusher tube in the distal direction, using an external control handle to which is coupled a proximal portion of the deployment manipulator tube and a proximal end of the pusher tube. For some applications, controllably releasing includes controllably releasing the pusher tube incrementally in the distal direction by one or more set distances.

For some applications, placing includes removably coupling the distal end of the pusher tube to the proximal end of the sleeve. For some applications, removably coupling includes using one or more one or more coupling elements of the pusher tube to removably couple the distal end of the pusher tube to the proximal end of the sleeve. For some applications, removably coupling includes positioning the deployment manipulator tube within the lumen of the sleeve such that the deployment manipulator tube causes the coupling elements to engage the sleeve, and the method further includes decoupling the distal end of the pusher tube from the proximal end of the sleeve by withdrawing the deployment manipulator tube from the sleeve such that the coupling elements disengage from the sleeve. For some applications, the coupling elements are configured to have a natural tendency to flex inwards toward a central longitudinal axis of the sleeve that passes through the proximal end of the sleeve, and the deployment manipulator tube, when positioned within the lumen of the sleeve, pushes the coupling elements outwards away from the longitudinal axis, thereby causing the coupling elements to engage the sleeve.

For some applications, the method further includes deploying at least one anchor through a wall of the sleeve using an anchor driver that is at least partially positioned within the deployment manipulator tube.

For some applications, the annuloplasty ring is a partial annuloplasty ring, and removably positioning includes removably positioning the deployment manipulator tube partially within the lumen of the partial annuloplasty ring.

There is still further provided, in accordance with an application of the present invention, a method including:

advancing, into a body of a subject, (a) an anchor driver, which includes a driver head, which is shaped so as to define one or more mechanical coupling elements, and which includes a flexible ring, and (b) an anchor, which includes (i) a coupling head, which is shaped so as to define: (A) one or more mating elements corresponding to the mechanical coupling elements, and configured to engage the mechanical coupling elements such that rotation of the mechanical coupling elements rotates the mating elements, which in turn rotate the coupling head, and (B) an outer coupling surface, sized to be inserted into and engage the flexible ring, and (ii) a tissue coupling element, which is fixed to the coupling head; and

rotating the mechanical coupling elements to cause the tissue coupling element of the anchor to screw itself into tissue of the body, thereby causing separation of: (a) the outer coupling surface of the coupling head from the flexible ring, and (b) the mating elements of the coupling head from the corresponding mechanical coupling elements.

For some applications, the outer element is configured to rotate freely with respect to the inner mating component.

For some applications, the coupling surface of the coupling head is shaped so as to define a screw thread, such that rotating the mechanical coupling elements causes the outer coupling surface to unscrew from the flexible ring.

For some applications, the mechanical coupling elements of the driver head include protrusions, and the mating elements of the coupling head include slots.

For some applications, advancing the anchor driver includes removably positioning the anchor driver within a lumen of a sleeve of an annuloplasty ring.

For some applications, the coupling element is shaped so as to define a shape selected from the group consisting of: a helix, a spiral, and a screw shaft.

The present invention will be more fully understood from the following detailed description of embodiments thereof, taken together with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A and **1**B are schematic illustrations of an adjustable partial annuloplasty ring in a non-contracted state, in accordance with respective applications of the present invention;

FIG. **2** is a schematic longitudinal cross-sectional illustration of an anchor deployment manipulator, in accordance with an application of the present invention;

FIG. **3** is a schematic longitudinal cross-sectional illustration of the anchor deployment manipulator of FIG. **2** advanced into the annuloplasty ring of FIG. **1**A, in accordance with an application of the present invention;

FIG. **4** is a schematic cross-sectional illustration of the anchor deployment manipulator of FIG. **2** advanced into the annuloplasty ring of FIGS. **1**A or **1**B, taken along section Iv-Iv of FIG. **3**, in accordance with an application of the present invention;

FIGS. **5**A-B are schematic illustrations of a rotation tool being used to rotate a spool of a contracting mechanism of the rings of FIGS. **1**A and **1**B, respectively, in accordance with respective applications of the present invention;

FIGS. **6**A and **6**B are schematic isometric and cross-sectional illustrations, respectively, of another configuration of a rotation tool being used to rotate a spool of a contracting mechanism of the ring of FIG. **1**B, in accordance with an application of the present invention;

FIG. **7** shows a relationship among individual components of the contracting mechanism of FIGS. **6**A and **6**B, in accordance with an application of the present invention;

FIG. **8** is another cross-sectional illustration of the contracting mechanism of FIGS. **6**A and **6**B, in accordance with an application of the present invention;

FIGS. **9**A-C are schematic cross-sectional illustrations of a rotation handle, in accordance with an application of the present invention;

FIGS. **10**A-D are schematic isometric illustrations of the rotation handle of FIGS. **9**A-C, in accordance with an application of the present invention;

FIGS. **11**A-I are schematic illustrations of a procedure for implanting the annuloplasty ring of FIG. **1**A to repair a mitral valve, in accordance with an application of the present invention;

FIG. **12** is a schematic illustration of the deployment of an anchor into cardiac tissue, in accordance with an application of the present invention;

FIG. **13** is a schematic illustration of the system of FIGS. **1-4** comprising a flexible pusher element, in accordance with an application of the present invention;

FIG. **14** is a schematic illustration of a pusher tube applied to a proximal end of the sleeve of FIGS. **1-4**, in accordance with an application of the present invention;

FIGS. **15** and **16** are schematic illustrations of the system of FIGS. **1-4** comprising a steerable tube, in accordance with respective applications of the present invention;

FIG. **17** is a schematic illustration of the system of FIGS. **1-4** comprising a pulling wire, in accordance with an application of the present invention;

FIGS. **18**A and **18**B are schematic illustrations of another configuration of the pusher tube of FIG. **14**, in accordance with an application of the present invention;

FIG. **19** is a schematic illustration of the system of FIGS. **1-4** and FIGS. **18**A-B comprising an external control handle, in accordance with an application of the present invention;

FIGS. **20**A-E are schematic cross-sectional and isometric illustrations of a configuration of a driver head of an anchor driver, in accordance with an application of the present invention;

FIG. **21** is a schematic illustration of an implant structure comprising repair chords, in accordance with an application of the present invention;

FIGS. **22**A and **22**B are schematic illustrations of another implant structure comprising repair chords, in accordance with respective applications of the present invention;

FIG. **23** is a schematic illustration of another configuration of a contracting mechanism and an implant structure, in accordance with an application of the present invention; and

FIGS. **24**A-B and **25** are schematic illustrations of a valve prosthesis assembly, in accordance with an application of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

FIGS. **1-4** are schematic illustrations of a system **20** for repairing a dilated atrioventricular valve, such as a mitral valve, in accordance with an application of the present invention. System **20** comprises an adjustable partial annuloplasty ring **22**, shown alone in FIGS. **1**A and **1**B in a non-contracted state, and an anchor deployment manipulator **24**, shown alone in FIG. **2**. Annuloplasty ring **22** comprises a flexible sleeve **26**. Anchor deployment manipulator **24** is advanced into sleeve **26**, as shown in FIGS. **3** and **4**, and, from within the sleeve, deploys anchors **38** through a wall of the sleeve into cardiac tissue, thereby anchoring the ring around a portion of the valve annulus.

FIGS. **1**A and **1**B are schematic illustration of annuloplasty ring **22** in a non-contracted state, in accordance with respective applications of the present invention. Sleeve **26** is typically configured to be placed only partially around the valve annulus (i.e., to assume a C-shape), and, once anchored in place, to be contracted so as to circumferentially tighten the valve annulus. Alternatively, the ring is configured to be placed entirely around the valve annulus. In order to tighten the annulus, annuloplasty ring **22** comprises a flexible elongated contracting member **30** that extends along the ring.

Annuloplasty ring **22** further comprises a contracting mechanism **40**, which facilitates contracting of the annuloplasty ring. Contracting mechanism **40** is described in more detail hereinbelow. In addition, the ring comprises a plurality of anchors **38**, typically between about 5 and about 20 anchors, such as about 10 or about 16 anchors. In FIGS. **1**A and **1**B, anchors **38** are shown prior to their insertion into ring **22**, while in FIG. **3** one of the anchors is shown deployed through the wall of sleeve **26**, and a second one of the anchors is shown during deployment by anchor deployment manipulator **24**. The insertion of the anchors into the sleeve and deployment of the anchors into cardiac tissue is described in detail hereinbelow.

Flexible sleeve **26** may comprise a braided, knitted, or woven mesh or a tubular structure comprising ePTFE. For some applications, the braid comprises metal and fabric fibers. The metal fibers, which may comprise Nitinol for example, may help define the shape of the sleeve, e.g., hold the sleeve open to provide space for passage and manipulation of deployment manipulator **24** within the sleeve. The fabric fibers may promote tissue growth into the braid. Optionally, the sleeve is somewhat elastic, which gives the sleeve a tendency to longitudinally contract, thereby helping tighten the sleeve. For example, the sleeve may be bellows- or accordion-shaped.

Typically, the sleeve is configured to have a tendency to assume a straight shape. This straightness helps the surgeon locate the next site for each subsequent anchor during the implantation procedure, as described hereinbelow with reference to FIGS. **11**A-I. For example, because the sleeve assumes a generally straight shape, the sleeve may help provide an indication of distance between adjacent anchoring sites.

For some applications, the sleeve is configured to have a controllably variable stiffness. For example, a somewhat stiff wire may be placed in the sleeve to provide the stiffness, and subsequently be removed at the conclusion of the implantation procedure when the stiffness is no longer useful.

Elongated contracting member **30** comprises a wire, a ribbon, a rope, or a band, which typically comprises a flexible and/or superelastic material, e.g., nitinol, polyester, stainless steel, or cobalt chrome. For some applications, the wire comprises a radiopaque material. For some applications, contracting member **30** comprises a braided polyester suture (e.g., Ticron). For some applications, contracting member **30** is coated with polytetrafluoroethylene (PTFE). For some applications, contracting member **30** comprises a plurality of wires that are intertwined to form a rope structure.

For some applications, contracting member **30** is positioned at least partially within a lumen of the sleeve **26**, such as entirely within the lumen (as shown in FIGS. **1**A-B, **5**A-B, **6**A, **11**H, and **11**I). For some applications in which the contracting member is positioned partially within the lumen, the contracting member is sewn into the wall of the sleeve, such that the contracting member is alternatingly inside and outside of the sleeve along the length of the sleeve (as shown in FIGS. **3**, **13**, and **14**). Optionally, sleeve **26** defines an internal channel within which member **30** is positioned (configuration not shown). Alternatively, the contracting member is disposed outside the lumen of the sleeve, such as alongside an outer wall of the sleeve. For example, sleeve **26** may define an external channel within which member **30** is positioned, or the sleeve may comprise or be shaped so as to define external coupling elements, such as loops or rings (configuration not shown). For some applications, contracting member **30** is positioned approximately opposite the anchors.

For some applications of the present invention, contracting mechanism **40** comprises a rotatable structure, such as a spool **46**. The rotatable structure is arranged such that rotation thereof contracts annuloplasty ring **22**. For some applications, a first end **47** of contracting member **30** is coupled to the spool. For some applications, contracting mechanism **40** further comprises a housing **44** that houses the rotatable structure, e.g., the spool. Spool **46** is positioned in a vicinity of (e.g., within 1 cm of) either a distal end **51** of sleeve **26**, as shown in FIGS. **1**A and **3**, or a proximal end **49** of sleeve **26**, as shown in FIG. **1**B. For some applications, a second end **53** of contracting member **30** is coupled to the sleeve in a vicinity of (e.g., within 1 cm of) the end of the sleeve opposite the end to which the spool is positioned. In the configuration shown in FIGS. **1**A and **3**, second end **53** of contracting member **30** is coupled to the sleeve in a vicinity of proximal end **49** of the sleeve, while in the configuration shown in FIG. **1**B, the second end of the contracting member is coupled to the sleeve in a vicinity of distal end **51** of the sleeve. Rotation of spool **46** winds a portion of the contracting member around the spool, thereby pulling the far end of the ring toward the spool and shortening and tightening the ring.

Alternatively, in some configurations, spool **46** is positioned at an intermediary position along the sleeve, rather than in a vicinity of one of the ends. For these configurations, contracting member **30** comprises two contracting members, which are respectively connected to the two ends of the sleeve, and both of which are connected to the spool. Rotating the spool contracts both contracting members. These configuration may be implemented using techniques described in U.S. patent application Ser. No. 12/341,960 to Cabiri, which is incorporated herein by reference, with reference to FIG. **15** thereof.

For some applications, spool **46** is shaped to provide a hole **42** or other coupling mechanism for coupling first end **47** of contracting member **30** to the spool, and thereby to contracting mechanism **40**.

For other applications, contracting member **30** comprises at least one wire (e.g., exactly one wire) that passes through a coupling mechanism of spool **46**, in order to couple the wire to the spool. The ends of the wire are brought together, and together serve as second end **53** of contracting member **30**, and may be coupled to one of the several locations of the sleeve mentioned hereinabove. In this configuration, approximately the longitudinal center of the wire serves as first end **47** of the contracting member.

For some applications, spool **46** is shaped to define a driving interface **48**. For some applications, driving interface **48** is female. For example, the interface may be shaped to define a channel which extends through the cylindrical portion of spool **46** from an opening provided by an upper surface **50** of spool **46** to an opening provided by a lower surface **52** of spool **46**. Alternatively, driving interface **48** is shaped so as to define an indentation (e.g., a groove) that does not extend entirely through the cylindrical portion of the spool. Further alternatively, driving interface **48** is male, and defines a protrusion, e.g., a hexagonal head or a head having another shape.

For some applications, a distal portion of a rotation tool **80**, which is described hereinbelow with reference to FIGS. **5**A-B, engages spool **46** via driving interface **48** and rotates spool **46** in response to a rotational force applied to the rotation tool. The rotational force applied to the rotation tool rotates spool **46** via the portion of the rotation tool that engages driving interface **48** of spool **46**.

Spool **46** typically comprises a locking mechanism that prevents rotation of the spool after contracting member **30** has been tightened. For example, locking techniques may be used that are described with reference to FIG. **4** of above-mentioned U.S. application Ser. No. 12/341,960 to Cabiri, which published as US Patent Application Publication 2010/0161047, and/or with reference to FIGS. **6**B, **7**, and **8** hereinbelow.

Alternatively, for some applications, contracting mechanism **40** is configured to tighten contracting member **30**, crimp the contracting member to hold the contracting member taut, and subsequently cut the excess length of the contracting member.

FIG. **2** is a schematic longitudinal cross-sectional illustration of anchor deployment manipulator **24**, FIG. **3** is a schematic longitudinal cross-sectional illustration of the anchor deployment manipulator advanced into annuloplasty ring **22**, and FIG. **4** is a schematic cross-sectional illustration of the anchor deployment manipulator advanced into the annuloplasty ring, taken along section Iv-Iv of FIG. **3**, in accordance with an application of the present invention. Anchor deployment manipulator **24** is advanced into a lumen of sleeve **26**, and, from within the lumen, deploys anchors **38** through a wall of the sleeve and into cardiac tissue, thereby anchoring the sleeve around a portion of the valve annulus. Typically, annuloplasty ring **22** and anchor deployment manipulator **24** are introduced into the heart via a sheath **104**, as described hereinbelow with reference to FIGS. **11**A-I.

For some applications, at least one of anchors **38** is deployed from a distal end **60** of deployment manipulator **24** while the distal end is positioned such that a central longitudinal axis **62** through distal end **60** of deployment manipulator **24** forms an angle α (alpha) of between about 45 and 90 degrees with the wall of sleeve **26** at the point at which the anchor penetrates the wall, such as between about 75 and 90 degrees, e.g., about 90 degrees. (In FIG. **3**, a line **64** schematically illustrates the plane tangential to the wall of the sleeve at the anchor-penetration point.) This anchor-penetration point is typically at a portion of the sleeve that extends distally beyond the distal end of outer tube **66** of deployment manipulator **24** (which is described hereinbelow), i.e., that is no longer in contact with the outer surface of outer tube **66**. Typically, all of the anchors are deployed at such angles, with the possible exception of the first anchor deployed near the distal end of the sleeve.

For some applications, at least one of anchors **38** is deployed from distal end **60** of deployment manipulator **24** while distal end **60** is positioned such that longitudinal axis **62** through distal end **60** of deployment manipulator **24** forms an angle β (beta) of between about 45 and 90 degrees (such as between about 75 and 90 degrees, e.g., about 90 degrees) with a line **65** defined by (a) a first point **67** at which the anchor currently being deployed penetrates the wall of the sleeve and (b) a second point **69** at which a most recently previously deployed anchor penetrates the wall of sleeve **26**. Typically, all of the anchors are deployed at such angles, with the exception of the first anchor deployed near the distal end of the sleeve.

Typically, the anchors are deployed from distal end **60** of deployment manipulator **24** into the cardiac tissue in a direction parallel to central longitudinal axis **62**.

For some applications, anchor deployment manipulator **24** comprises an outer tube **66** (sometimes referred to herein, including in the claims, as a "deployment manipulator tube") and an anchor driver **68** which is at least partially positioned within tube **66**. Anchor driver **68** comprises an elongated, flexible shaft **70**, having at its distal end a driver head **72**. Rotation of the anchor driver screws the anchors into the cardiac tissue. Each of anchors **38** is shaped so as to define a coupling head **74** and a tissue coupling element **76**. The anchors are typically rigid. Tissue coupling elements **76** may, for example, be helical or spiral in shape (e.g., having the shape of a corkscrew), as shown in the figures, may comprise screws, or may have other shapes. Coupling heads

74 may be either male (e.g., a hex or square protrusion) or female (e.g., a straight slot, a hex opening, a Phillips opening, or a Robertson opening). The use of helical anchors, which are screwed into the cardiac tissue, generally minimizes the force that needs to be applied during deployment of the anchors into the cardiac tissue. Alternatively, the anchors may comprise staples, clips, spring-loaded anchors, or other tissue anchors described in the references incorporated hereinabove in the Background section, or otherwise known in the art. For some applications, anchor deployment manipulator **24** and/or anchors **38** are implemented using techniques described hereinbelow with reference to FIGS. **20**A-E.

For some applications, outer tube **66** of deployment manipulator **24** is steerable, as known in the catheter art, while for other applications, a separate steerable tube is provided, as described hereinbelow with reference to FIG. **15** or FIG. **16**. To provide steering functionality to deployment manipulator **24**, outer tube **66**, steerable tube **300** (FIG. **15**), or steerable tube **320** (FIG. **16**), as the case may be, typically comprises one or more steering wires, the pulling and releasing of which cause deflection of the distal tip of the tube.

For some applications of the present invention, each of tissue coupling elements **76** is shaped so as to define a longitudinal axis **78** (shown in FIGS. **1**A-B), and is configured to penetrate the cardiac tissue in a direction parallel to longitudinal axis **78**. Deployment manipulator **24** is configured to deploy tissue coupling element **76** from distal end **60** of the deployment manipulator through the wall of sleeve **26** in a direction parallel to longitudinal axis **78** and parallel to central longitudinal axis **62** through distal end **60** of deployment manipulator **24** (shown in FIGS. **2**, **3**, and **12**-**15**).

For some applications, the plurality of anchors are applied using the deployment manipulator by loading a first one of the anchors onto the anchor driver, and deploying the anchor into the cardiac tissue. The anchor driver is withdrawn from the subject's body (typically while leaving outer tube **66** of the deployment manipulator in place in the sleeve), and a second one of the anchors is loaded onto the anchor driver. The anchor driver is reintroduced into the outer tube of the deployment manipulator, and the second anchor is deployed. These steps are repeated until all of the anchors have been deployed. Alternatively, the entire deployment manipulator, including the anchor driver, is removed from the body and subsequently reintroduced after being provided with another anchor. Further alternatively, the deployment manipulator is configured to simultaneously hold a plurality of anchors, and to deploy them one at a time (configuration not shown).

Typically, the first anchor **38** is deployed most distally in sleeve **26** (generally at or within a few millimeters of a distal end **51** of the sleeve), and each subsequent anchor is deployed more proximally, such that sleeve **26** is gradually pulled off (i.e., withdrawn from) deployment manipulator **24** in a distal direction during the anchoring procedure. Typically, as the sleeve is pulled off the deployment manipulator, the deployment manipulator is moved generally laterally along the cardiac tissue, as shown in FIG. **3**.

For some applications, an implant structure is provided. The implant structure comprises a contracting mechanism, such as contracting mechanism **40**. The contracting mechanism comprises a rotatable structure, arranged such that rotation of the rotatable structure contracts the implant structure. The implant further comprises a longitudinal member, which is coupled to the contracting mechanism. A tool, such as rotation tool **80**, is provided for rotating the rotatable structure. The tool is configured to be guided over the longitudinal member, to engage the rotatable structure, and to rotate the rotatable structure in response to a rotational force applied to the tool.

Reference is now made to FIGS. **5**A-B, which are schematic illustrations of rotation tool **80** being used to rotate spool **46** of contracting mechanism **40** of ring **22**, in accordance with respective applications of the present invention. For these applications, the implant structure comprises annuloplasty ring **22**. Rotation tool **80** has a head **82** that is either male (e.g., comprising a screwdriver head, having, such as a slot-head, an Allen-head, a Phillips-head, a Robertson-head, or a hex-head) or female (e.g., comprising a wrench head, having, for example, a square or hex opening), as appropriate for the driving interface provided. Typically, the rotation tool comprises a shaft **84**, at least a portion of which is flexible. For some applications, the rotation tool is used that is described in above-referenced U.S. patent application Ser. No. 12/341,960, which published as US Patent Application Publication 2010/0161047, with reference to FIG. **4** thereof. Alternatively, anchor driver **68** of deployment manipulator **24** serves as rotation tool **80**, and is used to rotate the spool, in which case driving interface **48** is appropriately shaped to receive driver head **72** of anchor driver **68**.

In the configuration shown in FIG. **5**A, contracting member **30** is coupled to distal end **51** of sleeve **26**, as shown hereinabove in FIGS. **1**A and **3**. Contracting mechanism **40** is oriented such that driving interface **48** thereof is accessible from within sleeve **26**. Rotation tool **80** is inserted into sleeve **26**, and used to rotate spool **46** via the driving interface. Alternatively, anchor driver **68** of deployment manipulator **24** serves as rotation tool **80**, and is used to rotate the spool, in which case driving interface **48** is appropriately shaped to engage driver head **72** of anchor driver **68**. In either case, the sleeve thus serves to guide the rotation tool to driving interface **48**. For some applications, an interior surface of the sleeve is tapered near the distal end of the sleeve, to help guide the head **82** of rotation tool **80** to the driving interface. For some applications, during the implantation procedure, anchor deployment manipulator **24** is left slightly inserted into proximal end **49** of sleeve **26** after all of anchors **38** have been deployed, in order to facilitate passage of rotation tool **80** into sleeve **26**.

In the configuration shown in FIG. **5**B, access to driving interface **48** is provided from outside sleeve **26**. For some applications, contracting mechanism **40** comprises a longitudinal member **86**, such as a wire, that is attached to the mechanism and passes out of the body of the subject, typically via sheath **104**. In order to readily bring the rotation tool to driving interface **48**, rotation tool **80** is guided over (as shown) the longitudinal member, or alongside the longitudinal member (configuration not shown). Alternatively, the longitudinal member comprises a suture or other highly flexible element. For some applications, the longitudinal member comprises a tube, through which rotation tool **80** is passed to bring the tool to the driving interface **48**. For some applications, longitudinal member **86** has a diameter of between 0.1 and 1 mm, such as 0.4 mm.

For some applications, longitudinal member **86** is looped through contracting mechanism **40**, and both ends of the longitudinal member are brought together and extend outside of the subject's body. The longitudinal member is decoupled from the contracting mechanism by releasing one end of the longitudinal member, and pulling on the other end to draw the longitudinal member away from the contracting mechanism.

For some applications, contracting mechanism **40** is positioned in a vicinity of (e.g., within 1 cm of) distal end **51** of sleeve **26**, and access to driving interface **48** is provided from outside sleeve **26**, as described with reference to FIG. **5**B (in which the contracting mechanism is positioned in a vicinity of proximal end **49** of the sleeve).

For some applications in which access to driving interface **48** is provided from outside sleeve **26**, the rotation tool is initially removably attached to the driving interface, prior to the commencement of the implantation procedure, and is subsequently decoupled from the driving interface after spool **46** has been rotated. In these applications, contracting mechanism **40** may be positioned in a vicinity of distal end **51** or proximal end **49** of sleeve **26**, or at an intermediate location along the sleeve. Optionally, at least a portion of a shaft of the rotation tool is positioned within sheath **104**, which is described hereinbelow with reference to FIGS. **11**A-I.

Reference is now made to FIGS. **6**A and **6**B, which are schematic isometric and cross-sectional illustrations, respectively, of another configuration of rotation tool **80** being used to rotate spool **46** of contracting mechanism **40** of ring **22**, in accordance with an application of the present invention. In this application, as in the configurations shown in FIGS. **1**B and **5**B, access to driving interface **48** is provided from outside sleeve **26**. Contracting mechanism **40** comprises longitudinal member **86** that is attached to the contracting mechanism **40** and passes out of the body of the subject, typically via sheath **104**. In order to readily bring the rotation tool to driving interface **48**, rotation tool **80** is guided over longitudinal member **86**. In this application, rotation tool **80** comprises one or more tubes that pass over the longitudinal member, as described below.

As mentioned above, for some application longitudinal member comprises a wire, which may comprise metal. Because the wire is fairly stiff, the wire generally maintains its direction and orientation with respect to contracting mechanism **40**. The wire thus readily guides the tubes to the contracting mechanism such that the tubes have a desired orientation and position with respect to the contracting mechanism.

Longitudinal member **86** is removably coupled to contracting mechanism **40**, typically to a central portion of upper surface **50** of spool **46**. For some applications, a distal portion **88** of longitudinal member **86** is shaped so as to define a screw thread **90**. Distal portion **88** is screwed into a threaded opening **92** of upper surface **50**, in order to removably couple longitudinal member **86** to contracting mechanism **40**. Typically, the distal portion is initially coupled to the contracting mechanism before annuloplasty ring **22** is placed into an atrium of the patient. As described below, the distal portion is decoupled from the contracting mechanism after spool **46** has been rotated to tighten ring **22**. For some applications, distal portion **88** comprises a discrete element that is fixed to longitudinal member **86**, while for other application, distal portion **88** is integral with longitudinal member **86**.

For some applications, rotation tool **80** comprises an inner (first) tube **98**, an intermediate (second) tube **96**, and, optionally, an outer (third) tube **94**. Rotation of each of the tubes is independently controlled, such as using techniques described hereinbelow with reference to FIGS. **9**A-C and/or **10**A-D. For some applications, a distal portion of each of tubes **94**, **96**, and **98** that enters the patient's body comprises braided plastic, and a proximal portion of each of the tubes that does not enter the patient's body comprises a hard material, such as metal (not shown). For example, the distal and proximal portions may have lengths of between 50 and 100 cm and between 50 and 350 cm, respectively. Distal-most portions **94**D, **96**D, and **98**D, respectively, of the distal portions typically comprise a hard material, such as metal, in order to engage other elements, as described immediately below. Typically, the distal-most portions comprise separate elements that are coupled to their respective tubes. For example, the distal-most portions may have lengths of between 1 and 10 mm.

Intermediate tube **96** is configured to rotate spool **46**. To this end, intermediate tube **96** (such as distal-most portion **96**D thereof) is configured to engage upper surface **50** of spool **46**. To enable such engagement, the upper surface typically is shaped so as to define one or more indentations **99** (e.g., grooves), in which corresponding protrusions at the distal end of intermediate tube **96** are positioned, such as by gently rotating tube **96** (or all of the tubes) until such engagement occurs. (Springs **460**, described hereinbelow with reference to FIGS. **9**A-C and **10**A-D, may be provided to assist with such engagement.) The radius of intermediate tube **96** is approximately equal to the distance of each of the indentations from a center of upper surface **50**, so that the protrusions at the distal end of the tube are aligned with the indentations. Alternatively, the upper surface defines one or more protrusions, which engage indentations on the distal end of tube **96** (configuration not shown). Indentations **99** or the protrusions thus serve as driving interface **48**.

Rotation of intermediate tube **96** causes corresponding rotation of spool **46**, thereby winding contracting member **30** around the spool, and tightening the contracting member.

Outer tube **94**, if provided, is configured to prevent rotation of spool housing **44** during rotation of spool **46**. To this end, outer tube **94** (such as distal-most portion **94**D thereof) is configured to engage an upper surface **160** of spool housing **44**. To enable such engagement, the upper surface typically is shaped so as to define one or more indentations **162** (e.g., grooves), in which corresponding protrusions at the distal end of outer tube **94** are positioned, such as by gently rotating the tube (or all of the tubes) until such engagement occurs. (Springs **460**, described hereinbelow with reference to FIGS. **9**A-C and **10**A-D, may be provided to assist with such engagement.) The radius of outer tube **94** is approximately equal to the distance of each of the indentations from a center of spool housing **44**, so that the protrusions at the distal end of the tube are aligned with the indentations. Alternatively, the upper surface defines one or more protrusions, which engage indentations on the distal end of tube **94** (configuration not shown).

During rotation of intermediate tube **96** for rotating spool **46**, outer tube **94** is held rotationally stationary, thereby stabilizing spool housing **44** and enabling spool **46** to rotate with respect to housing **44**.

Inner tube **98** is configured to decouple longitudinal member **86** from spool **46** after contracting member **30** has been sufficiently wound around the spool, as described above. To this end, a distal portion of the inner tube (such as distal-most portion **98**D thereof) is shaped so as to engage a distal portion of longitudinal member **86**, which is typically shaped so as to couple with the distal portion of the inner tube.

Rotation of the inner tube, while intermediate tube **96** is prevented from rotating and thus prevents rotation of spool **46**, causes corresponding rotation of longitudinal member **86**, and unscrews the longitudinal member from spool **46**. Longitudinal member **86** and spool **46** are typically configured such that this unscrewing rotation is in the opposite direction of the rotation of the spool that tightens the contracting member. For example, clockwise rotation of the spool (looking down on the spool) may wind the contracting member around the spool, while counterclockwise rotation of longitudinal member **86** unscrews the longitudinal member from the spool. To enable the engagement of inner tube **98** with the distal portion of the longitudinal member, the distal portion may include a flat portion.

FIG. **7** shows a relationship among individual components of contracting mechanism **40**, in accordance with an application of the present invention. Contracting mechanism **40** is shown as comprising spool housing **44** which defines an upper surface **160** and a recessed portion **176**. Spool **46** is configured to be disposed within housing **44** and defines an upper surface **178**, a lower surface **180** and a cylindrical body portion disposed vertically between surfaces **178** and **180**.

Lower surface **180** of spool **46** is shaped to define one or more (e.g., a plurality, as shown) recesses **182** which define structural barrier portions **188** of lower surface **180**. It is to be noted that any suitable number of recesses **182** may be provided, e.g., between 1 and 10 recesses, circumferentially with respect to lower surface **180** of spool **46**.

For some applications, as mentioned above, spool **46** comprises a locking mechanism **164**. For some applications, locking mechanism **164** is coupled, e.g., welded, at least in part to a lower surface of spool housing **44**. Typically, locking mechanism **164** defines a mechanical element having a planar surface that defines slits **184**. The surface of locking mechanism **164** may also be curved, and not planar. Locking mechanism **164** is shaped to provide a protrusion **166** which projects out of a plane defined by the planar surface of the mechanical element. The slits define a depressible portion **168** of locking mechanism **164** that is disposed in communication with and extends toward protrusion **166**. Depressible portion **168** is moveable in response to a force applied thereto by a distal element **70** that extends in a distal direction from distal portion **88** of longitudinal member **86**, beyond threaded opening **92** of upper surface **50**, as shown in FIG. **6**B.

It is to be noted that the planar, mechanical element of locking mechanism **164** is shown by way of illustration and not limitation and that any suitable mechanical element having or lacking a planar surface but shaped to define at least one protrusion may be used together with locking mechanism **164**.

A cap **170** is provided that is shaped so as to define a planar surface and an annular wall having an upper surface **186** that is coupled to, e.g., welded to, a lower surface of spool housing **44**. The annular wall of cap **170** is shaped so as to define a recessed portion **172** of cap **170** that is in alignment with recessed portion **176** of spool housing **44**.

Reference is again made to FIG. **6**B, and is additionally made to FIG. **8**, which is another cross-sectional illustration of contracting mechanism **40**, in accordance with an application of the present invention. FIG. **6**B shows contracting mechanism **40** in an unlocked state, while FIG. **8** shows the contracting mechanism in a locked state.

In the unlocked state shown in FIG. **6**B, protrusion **166** of locking mechanism **164** is disposed within recessed portion **172** of cap **170**. Longitudinal member **86** is shaped so as to define a distal force applicator **174** that extends distally, typically beyond screw thread **90**. In the unlocked state, the force applicator extends through spool **46** and pushes against depressible portion **168** of locking mechanism **164**. The depressible portion is thus pressed downward, as shown in FIG. **6**B, freeing protrusion **166** from within a recess **190** defined by structural barrier portions **188** of the lower portion of spool **46**. Additionally, protrusion **166** is freed from within recessed portion **176** provided by spool housing **44**. As a result, contracting mechanism **40** is unlocked, and spool **46** may be rotated with respect to spool housing **44**.

Cap **170** functions to restrict distal pushing of depressible portion **168** beyond a desired distance so as to inhibit deformation of locking mechanism **164**. For applications in which contracting mechanism **40** is implanted in heart tissue, cap **170** also provides an interface between contracting mechanism **40** and the heart tissue. This prevents interference of heart tissue on contracting mechanism **40** during the locking and unlocking thereof. Additionally, cap **170** prevents damage to heart tissue by depressible portion **168** as it is pushed downward.

In the locked state shown in FIG. **8**, protrusion **166** is positioned within a recess **190** of spool **46**. Typically, the locked state is the resting state of locking mechanism **162**. Depressible portion **168** is disposed in a horizontal position, in response to removal of distal force applicator **174** from within spool **46**. Depressible portion **168** has a tendency to assume the horizontal position, as shown, and in the absence of a downward pushing force applied to depressible portion **168** by force applicator **174**, depressible portion **168** returns to its horizontal position from its pushed-down state, as shown in FIG. **8**. In this horizontal position, protrusion **166** of locking mechanism **164** is removed from recessed portion **172** of cap **170** and is returned within a recess **190** of spool **46** and thereby restricts movement of spool **46** and locks contracting mechanism **40**. Additionally, protrusion **166** of locking mechanism **164** returns in part within recessed portion **176** of spool housing **44**. Thus, recessed portion **176** of spool housing **44** provides supplemental locking of locking mechanism **164**.

Reference is now made to FIGS. **9**A-C and **10**A-D, which are schematic cross-sectional and isometric illustrations, respectively, of a rotation handle **400**, in accordance with an application of the present invention. For some applications, rotation handle **400** is used for controlling rotation tool **80**, and thus the rotational positions of tubes **94**, **96**, and **98**, described hereinabove with reference to FIGS. **6**A-B. Alternatively, rotation handle **400** is used to rotate other tubes, such as for other medical applications.

Rotation handle **400** comprises a handle housing **410** and one or more knobs for controlling the rotation of the tubes. The housing is typically configured to be coupled to outer tube **94**, such that the outer tube cannot rotate with respect to the housing. The handle may comprise a hollow coupling element **412**, into which the outer tube is inserted and fixed. Intermediate tubes **96** and **98** are coupled to other elements of handle **400**, as described below.

As mentioned above, for some applications handle **400** is used with rotation tool **80**. For these applications, after annuloplasty ring **22** has been implanted, a proximal portion of longitudinal member **86** extends outside the patient's body, such as via sheath **104** (shown, for example, in FIGS. **2**, **11**C-I, and **12**). Tubes **94**, **96**, and **98** are threaded over this proximal portion of the longitudinal member, such that the longitudinal member is directly within inner tube **98**, which is in turn within intermediate tube **96**, which is in turn within outer tube **94**. The proximal end of longitudinal member **86** is threaded at least partially through the handle, such as entirely through the length of handle **400**, from a distal end **414** thereof to a proximal end **416** thereof.

Longitudinal member **86** is coupled to the handle such that the longitudinal member is longitudinally fixed to the housing (i.e., cannot be withdrawn), but is allowed to rotate with respect to the housing. For some applications, handle

400 comprises a longitudinal member coupling assembly **418**, for example positioned in a vicinity of proximal end **416** of the housing. Typically, longitudinal member coupling assembly **418** is configured to rotate with respect to the housing, thereby allowing longitudinal member **86** to rotate with respect to the housing. For some applications, longitudinal member coupling assembly **418** comprises a lever **452** that is biased by a spring **454** to pivot such that an end of the lever at a central longitudinal axis of handle **400** applies a force in a distal direction. The end of the level is shaped to allow longitudinal member **86** to be advanced toward proximal end **416** of handle **400**, while preventing withdrawal of the longitudinal member in a distal direction.

For some applications, rotation handle **400** comprises an intermediate-tube (second-tube) rotation knob **430** and an inner-tube (first-tube) rotation knob **432**. Optionally, intermediate-tube rotation knob **430** is positioned closer to distal end **414** of handle **400** than is inner-tube rotation knob **432**. Intermediate-tube rotation knob **430** is coupled to intermediate tube **96** (e.g., using an adhesive), such that rotation of the knob rotates the tube. Inner-tube rotation knob **432** is coupled to inner tube **98** (e.g., using an adhesive), such that rotation of the knob rotates the tube. The two knobs thus enable convenient rotation of the tubes, either separately or together.

For some applications, rotation handle **400** further comprises a control knob **434**, which, for some applications, is configured to slide longitudinally in distal and proximal directions over knobs **430** and **432**. When control knob **434** is positioned in a first position (e.g., a first longitudinal position, such as a proximal position, as shown in FIGS. **9**A and **9**B), an inner surface of the control knob engages both knobs **430** and **432**. Rotation of the control knob thus rotates both intermediate-tube rotation knob **430** (and thus intermediate tube **96**) and inner-tube rotation knob **432**, (and thus inner tube **98**). The rotation of intermediate tube **96** rotates spool **46**, as described hereinabove with reference to FIGS. **6**A-B. The rotation of inner tube **98** rotates longitudinal member **86** at the same rate as the spool is rotated, such that longitudinal member **86** remains screwed into the spool. For some applications, the inner surface of the control knob is shaped so as to define ridges which matingly engage troughs defined by external surfaces of knobs **430** and **432**.

When control knob **434** is positioned in a second position (e.g., a second longitudinal position, such as a distal position, as shown in FIG. **9**C), (a) an inner surface of control knob **434** engages intermediate-tube rotation knob **430** but not inner-tube rotation knob **432**, leaving knob **432** free to rotate independently of control knob **434**, and (b) an outer surface of control knob **434** engages housing **410**, rotationally fixing the control knob, and thus intermediate-tube rotation knob **430**, to the housing. Handle **400** thus prevents rotation of intermediate tube **96** and outer tube **94**, while allowing rotation of inner tube **98**. While intermediate tube **96** is prevented from rotating and thus prevents rotation of spool **46**, rotation of inner tube **98** causes corresponding rotation of longitudinal member **86**, and unscrews the longitudinal member from spool **46**, as described hereinabove with reference to FIGS. **6**A-B.

The outer surface of control knob **434** may be shaped so as to define ridges, protrusions **440** (as best seen in FIG. **10**D), teeth, or other engagement surfaces, for engaging housing **410**, an inner surface of which may define complementary engagement surfaces, such as troughs.

For some applications, when in the first position control knob **434** is closer to proximal end **416** of handle **400**, as shown in FIGS. **9**A and **9**B, and when in the second position control knob **434** is closer to distal end **414** of handle **400**, as shown in FIG. **9**C.

For some applications, when control knob **434** is positioned in the first longitudinal position (such as a proximal position, as shown in FIGS. **9**A, **9**B, and **10**A-C), the control knob at least partially (typically entirely) covers inner-tube rotation knob **432**, thereby preventing access to knob **432** by the surgeon. When control knob **434** is subsequently positioned in the second longitudinal position (such as a distal position, as shown in FIGS. **9**C and **10**D), the control knob reveals (i.e., no longer covers) inner-tube rotation knob **432**. The surgeon thus has convenient access to exposed knob **432**, as best seen in FIG. **10**D. Housing **410** is also shaped so as to enable such access, as can be seen, for example, in FIG. **10**D.

For some applications, control knob **434** does not slide, and instead assumes the first and second positions in response to a non-sliding motion.

For some applications, handle **400** comprises one or more springs **460** that spring-load one or more of tubes **94**, **96**, and **98**, pushing the tubes in a distal direction. Such spring-loading pushes the tubes against the respective elements of contracting mechanism **40**, helping the tubes to engage the respective elements of the contracting mechanism, as described hereinabove with reference to FIGS. **6**A-B.

For some applications, rotation handle **400** comprises a spring locking mechanism **462**, which is configured to assume locking and released states. In the locking state, as shown in FIGS. **9**A and **10**A-B, the spring locking mechanism prevents one or more of tubes **94**, **96**, and **98** from advancing in a distal direction. For example, the mechanism may prevent tubes **94**, **96**, and **98** from advancing distally by preventing distal movement of coupling element **412**, intermediate-tube rotation knob **430**, and inner-tube rotation knob **432**, respectively. Preventing such distal movement holds the springs in relatively compressed states, and prevents the springs from applying force to the tubes. The tubes are more easily coupled to the respective elements of contracting mechanism **40** when the tubes are not spring-loaded.

For some applications, spring locking mechanism **462** comprises one or more pins **464**, such as three pins, which are configured to be inserted into housing **410** (e.g., into respective openings in the housing), and, when so inserted, to block the distal motion of respective elements of the rotation handle, such as coupling element **412**, intermediate-tube rotation knob **430**, and inner-tube rotation knob **432**.

In the released state, as shown in FIGS. **9**B-C and **10**C-D, spring locking mechanism **462** does not prevent tubes **94**, **96**, and **98** from advancing in the distal direction. For example, the mechanism may not prevent distal movement of coupling element **412**, intermediate-tube rotation knob **430**, and inner-tube rotation knob **432**. Releasing the tubes and/or these elements allows springs **460** to expand, thereby pushing the tubes in a distal direction, as best seen in FIG. **9**B. Such spring-loading pushes the tubes against the respective elements of contracting mechanism **40**, helping the tubes to engage the respective elements of the contracting mechanism, as described hereinabove with reference to FIGS. **6**A-B. Typically, the springs distally advance the tubes **94**, **96**, and **98** by distally moving coupling element **412**, intermediate-tube rotation knob **430**, and inner-tube rotation knob **432**, respectively, as shown in FIG. **9**B.

Reference is still made to FIGS. **10**A-D. FIG. **10**A shows rotation handle **400** after the tubes have been coupled to respective elements of the handle, as described above, and as the surgeon pulls longitudinal member **86** through handle **400** and out of proximal end **416** thereof. As described above, longitudinal member coupling assembly **418** may be provided to prevent withdrawal of the longitudinal member in a distal direction after the longitudinal member has been drawn sufficiently through the handle. FIG. **10**A also shows spring locking mechanism **462** in its locking state.

FIG. **10**B shows rotation handle **400** after the initial coupling of the tubes to contracting mechanism **40**. Because spring locking mechanism **462** is still in its locking state, springs **460** have not yet distally pushed the tubes, so the tubes have not yet fully engaged respective elements of the contracting mechanism.

FIG. **10**C shows rotation handle **400** after spring locking mechanism **462** has been released to its released state. This release allows springs **460** to distally push the tubes against respective elements of contracting mechanism **40** until the tubes fully engage respective elements of the contracting mechanism. Control knob **434** is shown in its first (proximal) longitudinal position, in which an inner surface of the control knob engages both knobs **430** and **432** (not visible in FIG. **10**C). Rotation of the control knob thus rotates both intermediate-tube rotation knob **430** (and thus intermediate tube **96**) and inner-tube rotation knob **432** (and thus inner tube **98**). The rotation of intermediate tube **96** rotates spool **46**, as described hereinabove with reference to FIGS. **6**A-B. The rotation of inner tube **98** rotates longitudinal member **86** at the same rate as the spool is rotated, such that longitudinal member **86** remains screwed into the spool.

FIG. **10**D shows rotation handle **400** after control knob **434** has been is positioned in its second (distal) longitudinal position, in which (a) an inner surface of control knob **434** engages intermediate-tube rotation knob **430** (not visible in FIG. **10**D) but not inner-tube rotation knob **432** (visible in FIG. **10**D), leaving knob **432** free to rotate independently of control knob **434**, and (b) an outer surface of control knob **434** engages housing **410**, rotationally fixing the control knob, and thus intermediate-tube rotation knob **430**, to the housing. Handle **400** thus prevents rotation of intermediate tube **96** and outer tube **94**, while allowing rotation of inner tube **98**. While intermediate tube **96** is prevented from rotating and thus prevents rotation of spool **46**, rotation of inner tube **98** causes corresponding rotation of longitudinal member **86**, and unscrews the longitudinal member from spool **46**, as described hereinabove with reference to FIGS. **6**A-B.

Reference is now made to FIGS. **11**A-I, which are schematic illustrations of a procedure for implanting annuloplasty ring **22** to repair a mitral valve **130**, in accordance with an application of the present invention. The procedure is typically performed with the aid of imaging, such as fluoroscopy, transesophageal echo, and/or echocardiography.

The procedure typically begins by advancing a semi-rigid guidewire **102** into a right atrium **120** of the patient, as shown in FIG. **11**A.

As show in FIG. **11**B, guidewire **102** provides a guide for the subsequent advancement of a sheath **104** therealong and into the right atrium. Once sheath **104** has entered the right atrium, guidewire **102** is retracted from the patient's body. Sheath **104** typically comprises a 14-20 F sheath, although the size may be selected as appropriate for a given patient. Sheath **104** is advanced through vasculature into the right atrium using a suitable point of origin typically determined for a given patient. For example:

- sheath **104** may be introduced into the femoral vein of the patient, through an inferior vena cava **122**, into right atrium **120**, and into a left atrium **124** transseptally, typically through the fossa ovalis;
- sheath **104** may be introduced into the basilic vein, through the subclavian vein to the superior vena cava, into right atrium **120**, and into left atrium **124** transseptally, typically through the fossa ovalis; or
- sheath **104** may be introduced into the external jugular vein, through the subclavian vein to the superior vena cava, into right atrium **120**, and into left atrium **124** transseptally, typically through the fossa ovalis.

For some applications of the present invention, sheath **104** is advanced through an inferior vena cava **122** of the patient (as shown) and into right atrium **120** using a suitable point of origin typically determined for a given patient.

Sheath **104** is advanced distally until the sheath reaches the interatrial septum.

As shown in FIG. **11**D, a resilient needle **106** and a dilator (not shown) are advanced through sheath **104** and into the heart. In order to advance sheath **104** transseptally into left atrium **124**, the dilator is advanced to the septum, and needle **106** is pushed from within the dilator and is allowed to puncture the septum to create an opening that facilitates passage of the dilator and subsequently sheath **104** therethrough and into left atrium **124**. The dilator is passed through the hole in the septum created by the needle. Typically, the dilator is shaped to define a hollow shaft for passage along needle **106**, and the hollow shaft is shaped to define a tapered distal end. This tapered distal end is first advanced through the hole created by needle **106**. The hole is enlarged when the gradually increasing diameter of the distal end of the dilator is pushed through the hole in the septum.

The advancement of sheath **104** through the septum and into the left atrium is followed by the extraction of the dilator and needle **106** from within sheath **104**, as shown in FIG. **11**E.

As shown in FIG. **11**F, annuloplasty ring **22** (with anchor deployment manipulator **24** therein) is advanced through sheath **104** into left atrium **124**.

As shown in FIG. **11**G, distal end **51** of sleeve **26** is positioned in a vicinity of a left fibrous trigone **142** of an annulus **140** of mitral valve **130**. (It is noted that for clarity of illustration, distal end **51** of sleeve **26** is shown schematically in the cross-sectional view of the heart, although left trigone **142** is in reality not located in the shown cross-sectional plane, but rather out of the page closer to the viewer.) Alternatively, the tip is positioned in a vicinity of a right fibrous trigone **144** of the mitral valve (configuration not shown). Further alternatively, the distal tip of the sleeve is not positioned in the vicinity of either of the trigones, but is instead positioned elsewhere in a vicinity of the mitral valve, such as in a vicinity of the anterior or posterior commissure. For some applications, outer tube **66** of anchor deployment manipulator **24** is steerable, as is known in the catheter art, while for other applications, a separate steerable tube is provided, as described hereinbelow with reference to FIG. **15** and FIG. **16**. In either case, the steering functionality typically allows the area near the distal end of the deployment manipulator to be positioned with six degrees of freedom. Once positioned at the desired site near the selected trigone, deployment manipulator **24** deploys a first anchor **38** through the wall of sleeve **26** into cardiac tissue near the trigone.

As shown in FIG. **11**H, deployment manipulator **24** is repositioned along annulus **140** to another site selected for deployment of a second anchor **38**. Typically, the first anchor is deployed most distally in the sleeve (generally at or within a few millimeters of the distal tip of the sleeve), and each subsequent anchor is deployed more proximally, such that the sleeve is gradually pulled off (i.e., withdrawn from) the deployment manipulator in a distal direction during the anchoring procedure. The already-deployed first anchor **38** holds the anchored end of sleeve **26** in place, so that the sleeve is drawn from the site of the first anchor towards the site of the second anchor. Typically, as the sleeve is pulled off (i.e., withdrawn from) the deployment manipulator, the deployment manipulator is moved generally laterally along the cardiac tissue, as shown in FIG. **11**H. Deployment manipulator **24** deploys the second anchor through the wall of the sleeve into cardiac tissue at the second site. Depending on the tension applied between the first and second anchor sites, the portion of sleeve **26** therebetween may remain tubular in shape, or may become flattened, which may help reduce any interference of the ring with blood flow.

For some applications, in order to provide the second and subsequent anchors, anchor driver **68** is withdrawn from the subject's body via sheath **104** (typically while leaving outer tube **66** of the deployment manipulator in place in the sleeve), provided with an additional anchor, and then reintroduced into the subject's body and into the outer tube. Alternatively, the entire deployment manipulator, including the anchor driver, is removed from the body and subsequently reintroduced upon being provided with another anchor. Further alternatively, deployment manipulator **24** is configured to simultaneously hold a plurality of anchors, and to deploy them one at a time at the selected sites.

As shown in FIG. **11**I, the deployment manipulator is repositioned along the annulus to additional sites, at which respective anchors are deployed, until the last anchor is deployed in a vicinity of right fibrous trigone **144** (or left fibrous trigone **142** if the anchoring began at the right trigone). Alternatively, the last anchor is not deployed in the vicinity of a trigone, but is instead deployed elsewhere in a vicinity of the mitral valve, such as in a vicinity of the anterior or posterior commis sure.

As described hereinabove with reference to FIGS. **1**A and **1**B and/or FIGS. **6**A-**8**, rotation tool **80** or anchor driver **68** of deployment manipulator **24** is used to rotate spool **46** of contracting mechanism **40**, in order to tighten ring **22**. (For clarity of illustration, contracting member **30** of ring **22**, although provided, is not shown in FIGS. **11**A-I.) For some applications, rotation handle **400** is used to tighten the ring, such as described hereinabove with reference to FIGS. **9**A-C and/or **10**A-D. Alternatively, another technique is used to tighten the ring, such as described hereinabove.

For some applications, sleeve **26** is filled with a material (e.g., polyester, polytetrafluoroethylene (PTFE), polyethylene terephthalate (PET), or expanded polytetrafluoroethylene (ePTFE)) after being implanted. The material is packed within at least a portion, e.g., 50%, 75%, or 100%, of the lumen of sleeve **26**. The filler material functions to prevent (1) formation within the lumen of sleeve **26** of clots or (2) introduction of foreign material into the lumen which could obstruct the sliding movement of contracting member **30**.

For some applications, proximal end **49** of sleeve **26** is closed upon completion of the implantation procedure. Alternatively, the proximal end of the sleeve may have a natural tendency to close when not held open by deployment manipulator **24**.

Reference is made to FIG. **12**, which is a schematic illustration of the deployment of one of anchors **38** into cardiac tissue, in accordance with an application of the present invention. For these applications, one or more (such as all) of anchors **38** are deployed from left atrium **124**, through tissue of the atrial wall, and into tissue of an upper region of the ventricular wall **150** near the atrium. Because the tissue of the upper region of ventricular wall is thicker than that of the atrial wall, deploying the anchors into the upper region of the ventricular wall generally provides more secure anchoring. In addition, because the anchors are not deployed laterally through the atrial wall, the risk of perforating the atrial wall is reduced.

Annuloplasty ring **22** may be advanced toward annulus **140** in any suitable procedure, e.g., a transcatheter procedure, a percutaneous procedure, a minimally invasive procedure, or an open heart procedure (in which case one or more elements of system **20** are typically rigid). Regardless of the approach, the procedure typically includes the techniques described hereinabove with reference to FIGS. **11**G-I and **12**.

For some applications, following initial contraction of annuloplasty ring **22** during the implantation procedure, the ring may be further contracted or relaxed at a later time after the initial implantation, such as between several weeks and several months after the initial implantation. Using real-time monitoring, tactile feedback and optionally in combination with fluoroscopic imaging, a rotation tool or anchor driver **68** of deployment manipulator **24** is reintroduced into the heart and used to contract or relax annuloplasty ring **22**.

Reference is now made to FIG. **13**, which is a schematic illustration of system **10** comprising a flexible pusher element **200**, in accordance with an application of the present invention. Pusher element **200** aids with accurately positioning successive anchors **38** during an implantation procedure, such as described hereinabove with reference to FIGS. **11**H and **11**I. For some applications, pusher element **200** is positioned partially within tube **66** of deployment manipulator **24** such that a distal portion **204** of pusher element **200** extends distally out of tube **66**, through an opening **206** in a vicinity of a distal end of the tube (e.g., that is within 3 mm of the distal end, such as within 2 mm of the distal end). A proximal portion **202** of pusher element **200** passes through outer tube **66** from opening **206** to the proximal end of tube **66**. Opening **206** is provided either through a wall of the tube (as shown in FIG. **13**), or through the distal end of the tube (configuration not shown). Alternatively, pusher element **200** is positioned within sleeve **26**, but outside of tube **66** (configuration not shown). Typically, the pusher element is elongated, and is as least as long as sleeve **26**.

Pusher element **200** helps move the distal end of deployment manipulator **24** from a first site of the annulus at which the deployment manipulator has already deployed a first anchor (e.g., anchor **38**A in FIG. **13**) to a second site for deployment of a second anchor (e.g., anchor **38**B), in a direction indicated schematically by an arrow **210**. Pusher element **200** is pushed distally out of opening **206** of tube **66**, so that a distal end **212** of pusher element **200** engages and pushes against an interior surface of sleeve **26**, in a direction indicated schematically by an arrow **214**. The interior surface of the sleeve may be distal end **51** of the sleeve (as shown), or the wall of the sleeve at a location between distal end **51** and opening **206** (not shown). As a result, the distal end of deployment manipulator **24** moves in the opposite direction, i.e., as indicated by arrow **210**, toward a subsequent anchoring site. The movement in the direction of arrow **210** is generally along a line or curve defined by the portion of pusher element **200** already extended between the anchors that have already been deployed.

For some applications, as deployment manipulator **24** is positioned at successive deployment sites of the cardiac tissue, pusher element **200** is extended respective distances through opening **206**, each of which distances is successively greater. For other applications, after deployment manipulator **24** is positioned at each successive deployment site, the pusher element is pulled back in a proximal direction, and again extended a desired distance in a distal direction, such that the pusher element pushes again the wall of the sleeve (at a different location on the wall for each successive relocation of deployment manipulator **24**).

This technique thus aids in locating each subsequent anchoring site for deployment manipulator **24**. The pusher element may also help control the distance between adjacent anchoring sites, because they surgeon may push the pusher element a known distance after deploying each anchor.

Pusher element **200** typically comprises a strip, wire, ribbon, or band, and has a cross-section that is circular, elliptical, or rectangular. Pusher element **200** typically comprises a flexible and/or superelastic material, such as a metal such as nitinol, stainless steel, or cobalt chrome. Distal end **212** of pusher element **200** is dull, so that it does not penetrate sleeve **26**. For example, the distal end may be folded back, as shown in FIG. **13**.

FIG. **14** is a schematic illustration of a pusher tube **250** applied to proximal end **49** of sleeve **26**, in accordance with an application of the present invention. As shown in FIG. **14**, outer tube **66** is removably positioned partially within the lumen of sleeve **26**, such that outer tube **66** extends out of proximal end **49** of sleeve **26** (proximal end **49** can be seen in FIG. **1**B). Pusher tube **250** is configured to pass over outer tube **66**, such that a distal end of the pusher tube comes in contact with proximal end **49** of sleeve **26**. The pusher tube **250** is held in place against proximal end **49** of sleeve **26**, typically by an external control handle, such as external control handle **346**, described hereinbelow with reference to FIG. **17**, or external control handle **490**, described hereinbelow with reference to FIG. **19**. As the sleeve is pulled off (i.e., withdrawn from) outer tube **66** of the deployment manipulator in a distal direction, pusher tube **250** pushes sleeve **26** distally with respect to outer tube **66**, helping withdraw the sleeve from the outer tube. If the pusher tube were not provided, the wall of sleeve **26** might snag on outer tube **66** (as mentioned above, the sleeve may comprise braided or woven fabric). In addition, if such snagging occurs, gentle pushing with the pusher tube in the distal direction may help free the snag. For some applications, the techniques of this application are practiced in combination with those of the application described hereinbelow with reference to FIG. **17**.

FIG. **15** is a schematic illustration of system **10** comprising a steerable tube **300**, in accordance with an application of the present invention. For this application, outer tube **66** of deployment manipulator **24** is not steerable. Instead, to provide steering functionality, deployment manipulator **24** comprises a separate steering tube **300**, which is positioned around at least a portion of outer tube **66**. Outer tube **66**, because it does not provide this steering functionality, may have a smaller diameter than in the application described hereinabove with reference to FIG. **3**. Because outer tube **66** has a smaller diameter, sleeve **26** may also have a smaller diameter than in the application described hereinabove with reference to FIG. **3**. For some applications, the techniques of this application are practiced in combination with those of the application described hereinabove with reference to FIG. **14**. (Although in the application described with reference to FIG. **15**, system **10** typically comprises contracting member **30**, for clarity of illustration the contracting member is not shown in the figure.)

FIG. **16** is a schematic illustration of system **10** comprising a steerable tube **320**, in accordance with an application of the present invention. For this application, outer tube **66** of deployment manipulator **24** is not steerable. Steering functionality is instead provided by separate steering tube **320**, which is positioned around at least a portion of shaft **70** of anchor driver **68**, and within outer tube **66**. For some applications, the techniques of this application are practiced in combination with those of the application described hereinabove with reference to FIG. **14**. (Although in the application described with reference to FIG. **16**, system **10** typically comprises contracting member **30**, for clarity of illustration the contracting member is not shown in the figure.)

FIG. **17** is a schematic illustration of system **10** comprising a pulling wire **340**, in accordance with an application of the present invention. A distal portion **342** of pulling wire **340** is coupled to proximal end **49** of sleeve **26**, such as by passing through one or more holes near the proximal end. One or more proximal portions **344** of the pulling wire are coupled to an external control handle **346** of system **10**, which is manipulated by the surgeon outside of the subject's body. External control handle **346** is coupled to a proximal portion of outer tube **66**, such as a proximal end of the outer tube. Optionally, a portion of deployment manipulator **24** (e.g., a portion of outer tube **66**) which is never inserted in sleeve **26** comprises one or more coupling elements **348**, such as loops or tubes, through which pulling wire **340** passes in order to hold the pulling wire close to the external surface of the deployment manipulator. (Although in the application described with reference to FIG. **17**, system **10** typically comprises contracting member **30**, for clarity of illustration the contracting member is not shown in the figure.)

Pulling wire **340** holds sleeve **26** surrounding deployment manipulator **24**. The pulling wire is released in a distal direction as sleeve **26** is withdrawn from outer tube **66** of deployment manipulator **24** in a distal direction. The release of the sleeve allows the sleeve to gradually be withdrawn from the outer tube **66** of deployment manipulator **24**, in a controlled manner. In FIG. **17**, the sleeve is shown partially withdrawn from outer tube **66**, including the portion of the sleeve through which one of anchors **38** has been deployed.

For some applications, control handle **346** is configured to release pulling wire **340** incrementally in the distal direction, such that each time the wire is further released by respective set distances (typically, the distances are equal to one another). As a result, the sleeve is withdrawn from outer tube **66** of the deployment manipulator by this set distance (or respective distances), and subsequently-deployed anchors are approximately this set distance (or respective set distances) apart from one another. For example, the set distances may be between 2 mm and 15 mm, such as 4.5 mm. For some applications, the handle comprises a control ring **350** that is coupled to proximal portions **344** of the wire, and removably engages slots **352** on the handle that are spaced apart by this set distance. The slots thus set discrete positions for the ring and the wire. For some applications, control handle **346** is configured to allow control ring **350** to move only in the distal direction during a surgical procedure. Upon completion of the implantation procedure, in order to detach the pulling wire from the sleeve, one end of the wire may be cut or released, and the wire detached from the sleeve by pulling on the other end of the wire.

FIGS. **18**A and **18**B are schematic illustrations of another configuration of pusher tube **250**, described hereinabove with reference to FIG. **14**, in accordance with an application of the present invention. As described hereinabove with reference to FIG. **14**, pusher tube **250** passes over outer tube **66**, and pushes gently in a distal direction on proximal end **49** of sleeve **26**. The pusher tube is held in place against proximal end **49** of sleeve **26**, typically by an external control handle, such as external control handle **346**, described hereinabove with reference to FIG. **17**. As the sleeve is pulled off (i.e., withdrawn from) outer tube **66** of the deployment manipulator, pusher tube **250** pushes sleeve **26** distally with respect to outer tube **66**, helping withdraw the sleeve from the outer tube. If the pusher tube were not provided, the wall of sleeve **26** might snag on outer tube **66** (as mentioned above, the sleeve may comprise braided or woven fabric). In addition, if such snagging occurs, gentle pushing with the pusher tube in the distal direction may help free the snag.

In the configuration shown in FIG. **18**A, pusher tube **250** comprises one or more coupling elements **456** (such as exactly one coupling element or exactly two coupling elements). The coupling elements are configured to removably couple proximal end **49** of sleeve **26** to a distal end **458** of pusher tube **250**, thereby allowing sleeve **26** from moving distally with respect to outer tube **66** of deployment manipulator **24** only to the extent that pusher tube **250** is released in the distal direction, such as using external control handle **490**, described hereinbelow with reference to FIG. **19**.

For some applications, coupling elements **456** have a natural tendency to flex inwards (toward a central longitudinal axis of sleeve **26** that passes through the proximal end of the sleeve). Outer tube **66**, when positioned within the sleeve in a vicinity of the coupling elements, pushes the coupling elements outwards (away from the central longitudinal axis), causing the coupling elements to engage the sleeve. For example, the coupling elements may be curved to define outwardly-directed ends that push against or pierce the sleeve. Such pushing against or piercing engages the sleeve, which, as mentioned above, may comprise braided or woven fabric.

FIG. **18**B shows sleeve **26** released from coupling elements **456**. Proximal withdrawal of outer tube **66** from sleeve **26** (into or through pusher tube **250**) allows coupling elements **456** to assume their natural inwardly-flexed position, thereby releasing sleeve **26** from the coupling elements, and decoupling the sleeve from the pusher tube. As described hereinabove, sleeve **26** is gradually pulled off (i.e., withdrawn from) deployment manipulator **24**, including outer tube **66**, in a distal direction during the anchoring procedure. Outer tube **66** of deployment manipulator **24** is proximally withdrawn completely from the sleeve at the conclusion of the anchoring procedure. The flexing of the coupling elements releases the sleeve at the conclusion of the procedure.

FIG. **19** is a schematic illustration of system **10** comprising an external control handle **490**, in accordance with an application of the present invention. External control handle **490** is configured to be used with pusher tube **250**, as described hereinabove with reference to FIGS. **14** and/or **18**A-B. The handle is manipulated by the surgeon outside of the subject's body. External control handle **490** is coupled to a proximal portion of outer tube **66**, such a proximal end of the outer tube. For some applications, coupling elements **456** of pusher tube **250** couple proximal end **49** of sleeve **26** to distal end **458** of pusher tube **250**, as described hereinabove with reference to FIGS. **18**A-B (proximal end **49** can be seen in FIG. **18**B). A proximal end of pusher tube **250** is coupled to handle **490**. (Although in the application described with reference to FIG. **19**, system **10** typically comprises contracting member **30**, for clarity of illustration the contracting member is not shown in the figure.)

External control handle **490** is configured to release pusher tube **250** in a distal direction as sleeve **26** is withdrawn from outer tube **66** of deployment manipulator **24**. The release of pusher tube **250** releases sleeve **26**, and allows the sleeve to gradually be withdrawn from outer tube **66**, in a controlled manner. In FIG. **19**, the sleeve is shown partially withdrawn from outer tube **66**, including the portion of the sleeve through which one of anchors **38** has been deployed.

For some applications, control handle **490** is configured to release pusher tube **250** incrementally in the distal direction, such that each time the pusher tube is further released by respective set distances (typically, the distances are equal to one another). As a result, the sleeve is withdrawn from outer tube **66** of the deployment manipulator by this set distance (or respective distances), and subsequently-deployed anchors are approximately this set distance (or respective distances) apart from one another. For example, the set distances may be between 2 mm and 15 mm, such as 4.5 mm. For some applications, the handle comprises control ring **350** that is coupled to a proximal end of pusher tube **250**, and removably engages slots **352** on the handle that are spaced apart by this set distance. The slots thus set discrete positions for the ring and the pusher tube. For some applications, control handle **490** is configured to allow control ring **350** to move only in the distal direction during a surgical procedure. For some applications, upon completion of the implantation procedure, in order to detach the pusher tube from the sleeve, outer tube **66** of deployment manipulator **24** is proximally withdrawn completely from the sleeve, thereby causing the coupling elements to release the sleeve, such as described hereinabove with reference to FIG. **18**B.

Although annuloplasty ring **22** has been described hereinabove as comprising a partial annuloplasty ring, for some applications of the present invention, the ring instead comprises a full annuloplasty ring.

Reference is made to FIGS. **20**A-E, which are schematic cross-sectional and isometric illustrations of a configuration of driver head **72** of anchor driver **68**, in accordance with an application of the present invention.

Anchor driver **68** is described hereinabove, for example, with reference to FIG. **2**. Driver head **72** comprises an inner mating component **470**, which is coupled to a distal end **472** of flexible shaft **70**, such as by welding, such that inner mating component **470** is rotationally fixed to shaft **70**. (In this context, "inner" means closer to a longitudinal axis **473** of driver head **72**.) As shown in FIGS. **20**B and **20**D, a distal end of inner mating component **470** is shaped so as to define one or more (e.g., two) mechanical coupling elements, such as protrusions **474**. Coupling head **74** of anchor **38** is shaped so as to define corresponding mating elements, such as slots **476**, also shown in FIG. **20**B. Before implantation of anchor **38**, coupling head **74** is removably coupled to inner mating component **470** by the coupling and mating elements.

Driver head **72** further comprises an outer element **478**, which at least partially surrounds inner mating component **470** and extends in a distal direction beyond a distal end of inner mating component **470**. (In this context, "outer" means further from longitudinal axis **473** of driver head **72**.) Typically, outer element **478** is free to rotate with respect to inner mating component **470**. Outer element **478** is typically longitudinally fixed to the inner mating component. For example, the inner mating component may be shaped so as to define at least one lateral protrusion **480**, and the outer element may be shaped to define at least one corresponding recess **482**. Alternatively, one or more of inner mating component **470**, distal end **472** of flexible shaft **70**, and outer element **478** are welded together, or comprise a single element.

An outer surface of coupling head **74** of anchor **38** is typically shaped so as to define a screw thread **484**. The screw thread is initially screwed into a flexible ring **486** that is coupled to an inner surface of outer element **478**. The ring is sized to tightly engage the screw thread. The ring may comprise, for example, silicone, rubber, or a springy metal. For some applications, a distal portion of coupling head **74** (such as the portion that defines screw thread **484**) is conical.

During deployment of anchor **38** into tissue, such as described hereinabove with reference to FIGS. **2**, **3**, **11**G-H, **12**, **13**, **14**, **15**, and/or **16**, rotation of shaft **70** and inner mating component **470** causes corresponding rotation of anchor **38**. As tissue coupling element **76** of anchor **38** rotates, the tissue coupling element screws itself into the tissue, thereby advancing itself in a distal direction (to the right in FIG. **20**C) into the tissue. This rotation and distal advancement of the anchor unscrews screw thread **484** from flexible ring **486**, and, at the same time, separates the mating elements of coupling head **74** of the anchor from the coupling elements of inner mating component **470** of driver head **72**.

This configuration of driver head **72** and anchor **38** thus enables the anchor to self-disconnect from the driver head.

For some applications, anchor **38** is coupled to driver head **72** (typically during manufacture) by:

- aligning protrusions **474** with slots **476**;
- holding inner mating component **470** and tissue coupling element **76** rotationally stationary; and
- rotating outer element **478**, which causes flexible ring **486** to screw in screw thread **484** of coupling head **74**. As the coupling head is screwed into driver head **72**, protrusions **474** enter slots **476**.

Reference is now made to FIG. **21**, which is a schematic illustration of an implant structure **500** comprising repair chords **510**, in accordance with an application of the present invention. In this application, repair chords **510** function as artificial chordae tendineae, and comprise one or more longitudinal members **520** and **522**, e.g., sutures, wires, or elongate tensioning coils, which are coupled at respective first end portions thereof to a contracting mechanism **512**. Respective second end portions of the longitudinal members are coupled (e.g., tied, sutured, clipped, or otherwise fastened) to a second portion of tissue which faces and surrounds the ventricle, such as a leaflet **552** of an atrioventricular valve **554** (e.g., a mitral valve or a tricuspid valve). Longitudinal members **520** and **522** are knotted together using at least one suture knot **523**, and excess portions of longitudinal members **520** and **522** are cut away from the knot. Alternatively, any suitable anchor may be used instead of the knot. For example, longitudinal member **520** may comprise a male clip at its free end and longitudinal member **522** may comprise a female clip at its free end. In this case, longitudinal members **520** and **522** are clipped at their free ends to the leaflet. For some applications, anchors or clips may be used that are described in U.S. patent application Ser. No. 12/548,991, filed Aug. 27, 2009, which published as US Patent Application Publication 2010/0161042 and is incorporated herein by reference, such as with reference to one or more of FIGS. **9**A-**18**D and **22**A-**23**I thereof.

Implant structure **500** comprises a contracting mechanism assembly **514**, which comprises contracting mechanism **512** and a tissue anchor **550**. The tissue anchor facilitates implantation of the contracting mechanism assembly in a first portion of tissue of the heart which faces and surrounds the ventricular lumen, such as a papillary muscle **518**. Tissue anchor **550** is shown as a helical anchor by way of illustration and not limitation, and may comprise staples, clips, spring-loaded anchors, or other tissue anchors known in the art. Alternatively, contracting mechanism assembly **514** does not include tissue anchor **50** and is, instead, sutured to a portion of tissue of a ventricle wall which faces a ventricular lumen of a heart of a patient.

For some applications, contracting mechanism **512** comprises a rotatable structure, such as a spool (not visible in FIG. **21**, but typically similar to spool **46**, described hereinabove with reference to FIGS. **5**A-B, **6**A-B, **7**, and **8**), and, typically, a housing **516**, which houses the spool. First end portions of the longitudinal members are coupled to contracting mechanism **512**, typically to spool **46**.

Implant structure **500** comprises one or more longitudinal members **86**, which are coupled to contracting mechanism **512**, such as to housing **516** or to the spool. A rotation tool **530** is configured to pass over longitudinal members **86**, engage the spool of contracting mechanism **512**, and rotate the spool, thereby tightening the contracting mechanism, and shortening and tensioning longitudinal members **520** and **522**.

For some applications, implant structure **500** utilizes techniques described hereinabove with reference to FIGS. **5**A-B, **6**A-B, **7**, **8**, **9**A-C, and/or **10**A-D. For some applications, implant structure **500** utilizes techniques described in U.S. patent application Ser. No. 12/548,991, filed Aug. 27, 2009, which published as US Patent Application Publication 2010/0161042 and is incorporated herein by reference, such as with reference to one or more of FIGS. **3**-**18**D and **22**A-**23**I thereof.

Reference is made to FIGS. **22**A and **22**B, which are schematic illustrations of another implant structure **600** comprising repair chords **510**, in accordance with respective applications of the present invention. In these application, repair chords **510** are used to adjust a distance between two portions of the ventricular wall.

FIG. **22**A shows implant structure **600** comprising contracting mechanism assembly **514** implanted at a first portion **620** of heart tissue which faces and surrounds the left ventricle of the heart. The free ends of longitudinal members **520** and **522** are coupled to a second portion **622** of heart tissue which faces and surrounds the left ventricle, e.g., at the septum, by way of illustration and not limitation. The free ends of longitudinal members **520** and **522** are coupled to the heart tissue using any suitable attachment means **602**, e.g., sutures, knotting, or tissue anchors such as helical anchors.

Implant structure **600** comprises contracting mechanism assembly **514**, described hereinabove with reference to FIG. **20**. Implant structure **600** comprises one or more longitudinal members **86**, which are coupled to contracting mechanism **512**, such as to housing **516** or to the spool. Rotation tool **530** is configured to pass over longitudinal members **86**, engage the spool of contracting mechanism **512**, and rotate the spool, thereby tightening the contracting mechanism, and shortening and tensioning longitudinal members **520** and **522**. In response to the shortening of longitudinal members **520** and **522**, first and second portions **620** and **622** of the heart tissue are pulled toward one another. Consequently, the dimensions of the heart wall are restored to physiological dimensions, and the leaflets are drawn toward one another.

FIG. **22**B shows implant structure **700** for adjusting a distance between two portions of a heart wall of the left ventricle of the patient. Longitudinal members **520** and **522** are coupled at first portions thereof to a rotatable structure, e.g., a spool, of contracting mechanism **512**. Respective free ends of each member **520** and **522** are coupled to opposing first and second portions of the heart wall which faces and surrounds the ventricular lumen of the heart. The free end of longitudinal member **522** is coupled to first implantation site using a first helical anchor **750** by way of illustration and not limitation. For example, the free end of longitudinal member **522** is coupled to the first implantation site using sutures, knots, or any tissue anchor known in the art. The free end of longitudinal member **520** is coupled to a second implantation site using a second helical anchor **750** by way of illustration and not limitation. For example, the free end of longitudinal member **520** is coupled to the second implantation site using sutures, knots, or any tissue anchor known in the art. In such a configuration, contracting mechanism **512** is disposed between longitudinal members **520** and **522** and is not directly coupled to heart tissue.

Following the attaching of longitudinal members **520** and **522** to the first and second implantation sites, respectively, rotation tool **530** is passed over longitudinal members **86**, and used to rotate the spool of contracting mechanism **512**, such as described hereinabove. As described hereinabove, using tool **530**, the spool of contracting mechanism **512** is rotated in order to adjust a distance between the first and second implantation sites. Responsively, the first and second portions of the ventricle wall are drawn together. Consequently, the dimensions of the heart wall are restored to physiological dimensions, and the leaflets are drawn toward one another.

For some applications, implant structure **500** utilizes techniques described hereinabove with reference to FIGS. **5**A-B, **6**A-B, **7**, **8**, **9**A-C, and/or **10**A-D. For some applications, implant structure **500** utilizes techniques described in U.S. patent application Ser. No. 12/548,991, filed Aug. 27, 2009, which published as US Patent Application Publication 2010/0161042 and is incorporated herein by reference, such as with reference to one or more of FIGS. **19-21** thereof.

Reference is made to FIG. **23**, which is a schematic illustration of another configuration of contracting mechanism **40** and an implant structure **800**, in accordance with an application of the present invention. In this application, contracting mechanism **40** is used to adjust a length or circumference of implant structure **800**, which may comprise, for example, a partial or a full annuloplasty ring, such as ring **22**, or another implant structure. In this application, a first rotatable structure **810** is shaped so as to define a pinion **812**, and a first portion **813** of implant structure **800** is shaped so as to define a rack **814**. Geared teeth of pinion **812** matingly engage teeth of rack **814**, such that first portion **813** passes between first rotatable structure **810** and a second rotatable structure **816** that rotates on an axel **818** that is coupled to a second portion **820** of implant structure **800**. The first and second rotatable structures **810** and **816** are maintained at an appropriate distance from each other using a housing or bracket. (For clarity of illustration, the housing or bracket is not shown in the figure, because the housing or bracket is typically positioned on the further side of the rotatable structures that is not visible in the figure.) For example, the housing or bracket may connect the axels of the rotatable structures on the sides thereof opposite the sides shown in FIG. **23**. Alternatively, for some applications, second rotatable structure **816** is not provided, and first rotatable structure **810** is coupled directly to second portion **820** of implant structure **800**.

For applications in which implant structure **800** comprises a full band, such as a full annuloplasty ring, the first and second portions **813** and **820** of implant structure **800** are opposite ends of the same continuous structure. For applications in which implant structure comprises a partial band, such as a partial annuloplasty ring, the respective portions of first and second portions **813** and **820** are coupled near respective ends of a sleeve, or themselves define the ring.

Implant structure **800** comprises longitudinal member **86**, which is coupled to contracting mechanism **40**. Rotation tool **80** is provided for rotating first rotatable structure **810**. The tool is configured to be guided over the longitudinal member, to engage the rotatable structure, and to rotate the rotatable structure in response to a rotational force applied to the tool, such as using techniques described hereinabove with reference to FIGS. **5**A-B, **6**A-B, **7**, **8**, **9**A-C, and/or **10**A-D.

Reference is made to FIGS. **24**A-B and **25**, which are schematic illustrations of a valve prosthesis assembly **900**, in accordance with an application of the present invention. Valve prosthesis assembly **900** comprises a prosthetic heart valve **910** that is couplable to a base ring **922**. Prosthetic heart valve **910** is used to replace a native diseased heart valve. Valve **910** comprises a plurality of artificial leaflets **930**, which comprise a pliant material. Valve **910** may implement techniques known in the artificial valve art, such as described, for example, in US Patent Application Publication 2007/0255400 to Parravicini et al., US Patent Application Publication 2004/0122514 to Fogarty et al., US Patent Application Publication 2007/0162111 to Fukamachi et al., and/or US Patent Application Publication 2008/0004697 to Lichtenstein et al., all of which are incorporated herein by reference.

Valve **910** further comprises an annular base **932**, to which artificial leaflets **930** are coupled. Annular base **932** is configured to be couplable to base ring **922** during an implantation procedure. For example, as show in FIG. **25**, base ring **922** may comprise one or more coupling elements **934**, such as clips or magnets, which are configured to be coupled to corresponding coupling elements on a lower surface of annular base **932** (not visible in the figures). Alternatively or additionally, annular base **932** may be configured to be placed within the opening defined by base ring **922**, as shown in FIG. **24**A. To hold the annular base coupled to the base ring, the base ring is tightened around the annular base, as shown in FIG. **24**B, typically using one or more of the techniques described hereinabove for contracting implant structures. Typically, valve prosthesis assembly **900**, such as annular base **932** thereof, is configured to push and hold open the intact diseased native leaflets.

Base ring **922** implements one or more of the techniques of annuloplasty ring **22** described hereinabove. In particular, base ring **922** may be coupled to the annulus of the native diseased valve using the anchoring techniques described hereinabove. In addition, base ring **922** typically comprises a rotatable structure **936**, such as a spool, which is typically implemented using techniques described herein. The rotatable structure is arranged such that rotation thereof contracts base ring **922**, typically using techniques described herein. Such tightening may serve to couple base ring **922** to annular base **932**, as shown in FIG. **24**B. Alternatively or additionally, such tightening sets the desired dimensions of the base ring, in order to align the coupling elements of the base ring with those of valve **910**, thereby enabling tight coupling, such as for the applications described with reference to FIG. **25**.

For some applications, base ring **922** comprises a partial ring, as shown in FIG. **25**, while for other applications, the base ring comprises a full ring, as shown in FIGS. **24**A-B.

Valve prosthesis assembly **900** is typically implanted in a minimally invasive transcatheter or percutaneous procedure. The procedure begins with the introduction and implantation of base ring **922** into the heart, such as using techniques for implanting annuloplasty ring **22**, described hereinabove with reference to FIGS. **11**A-I. Prosthetic heart valve **910** is subsequently introduced into the heart and coupled to base ring **922**, as described above. Valve prosthesis assembly **900** is typically used for replacement of a diseased native mitral valve, aortic valve, tricuspid valve, or pulmonary valve.

For some applications of the present invention, system **20** is used to treat an atrioventricular valve other than the mitral valve, i.e., the tricuspid valve. For these applications, annuloplasty ring **22** and other components of system **20** described hereinabove as being placed in the left atrium are instead placed in the right atrium. Although annuloplasty ring **22** is described hereinabove as being placed in an atrium, for some application the ring is instead placed in either the left or right ventricle.

For some applications, techniques described herein are practiced in combination with techniques described in one or more of the references cited in the Background section of the present patent application.

Additionally, the scope of the present invention includes embodiments described in the following applications, which are incorporated herein by reference. In an embodiment, techniques and apparatus described in one or more of the following applications are combined with techniques and apparatus described herein:

PCT Publication WO 06/097931 to Gross et al., entitled, "Mitral Valve treatment techniques," filed Mar. 15, 2006;

U.S. Provisional Patent Application 60/873,075 to Gross et al., entitled, "Mitral valve closure techniques," filed Dec. 5, 2006;

U.S. Provisional Patent Application 60/902,146 to Gross et al., entitled, "Mitral valve closure techniques," filed on Feb. 16, 2007;

U.S. Provisional Patent Application 61/001,013 to Gross et al., entitled, "Segmented ring placement," filed Oct. 29, 2007;

PCT Patent Application PCT/IL07/001503 to Gross et al., entitled, "Segmented ring placement," filed on Dec. 5, 2007, which published as PCT Publication WO 08/068756;

U.S. patent application Ser. No. 11/950,930 to Gross et al., entitled, "Segmented ring placement," filed on Dec. 5, 2007, which published as US Patent Application Publication 2008/0262609;

US Provisional Patent Application 61/132,295 to Gross et al., entitled, "Annuloplasty devices and methods of delivery therefor," filed on Jun. 16, 2008;

U.S. patent application Ser. No. 12/341,960 to Cabiri, entitled, "Adjustable partial annuloplasty ring and mechanism therefor," filed on Dec. 22, 2008, which published as US Patent Application Publication 2010/0161047;

US Provisional Patent Application /207,908 to Miller et al., entitled, "Actively-engageable movement-restriction mechanism for use with an annuloplasty structure," filed on Feb. 17, 2009;

U.S. patent application Ser. No. 12/435,291 to Maisano et al., entitled, "Adjustable repair chords and spool mechanism therefor," filed on May 4, 2009, which published as US Patent Application Publication 2010/0161041;

U.S. patent application 12/437,103 to Zipory et al., entitled, "Annuloplasty ring with intra-ring anchoring," filed on May 7, 2009, which published as US Patent Application Publication 2010/0286767;

PCT Patent Application PCT/IL2009/000593 to Gross et al., entitled, "Annuloplasty devices and methods of delivery therefor," filed on Jun. 15, 2009, which published as PCT Publication WO 10/004546;

U.S. patent application Ser. No. 12/548,991 to Maisano et al., entitled, "Implantation of repair chords in the heart," filed on Aug. 27, 2009, which published as US Patent Application Publication 2010/0161042.

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove, as well as variations and modifications thereof that are not in the prior art, which would occur to persons skilled in the art upon reading the foregoing description.

The invention claimed is:

1. A method comprising performing each of the following steps during a transcatheter procedure:

placing, into a body of a subject, an implant structure, which includes (a) exactly one continuous flexible sleeve, and (b) a contracting mechanism that is directly coupled to a flexible longitudinal member and includes a rotatable structure, such that the flexible longitudinal member extends outside of the body; anchoring the implant structure to a tissue;

thereafter, guiding a tool along, over, and around the flexible longitudinal member to the rotatable structure by moving the tool;

thereafter, contacting and engaging the rotatable structure with the tool; and

thereafter, contracting the implant structure by rotating the rotatable structure using the tool, so as to contract the tissue.

2. The method according to claim **1**, wherein the flexible longitudinal member includes an element selected from the group consisting of: at least one wire, and a suture, and wherein guiding the tool along, over, and around the flexible longitudinal member comprises guiding the tool along, over, and around the selected element by moving the tool.

3. The method according to claim **2**, further comprising decoupling the flexible longitudinal member from the contracting mechanism after rotating the rotatable structure.

4. The method according to claim **3**, wherein a distal portion of the flexible longitudinal member is shaped so as to define a screw thread, wherein the contracting mechanism is shaped so as to define a threaded opening, into which the distal portion of the flexible longitudinal member is initially screwed, and wherein decoupling the flexible longitudinal member from the contracting mechanism comprises unscrewing the flexible longitudinal member from the threaded opening.

5. The method according to claim **3**, wherein the flexible longitudinal member is removably coupled to the rotatable structure of the contracting mechanism, and wherein decoupling the flexible longitudinal member from the contracting mechanism comprises decoupling the flexible longitudinal member from the rotatable structure.

6. The method according to claim 3, wherein the tool includes a tube, wherein guiding the tool along, over, and around the selected element comprises passing the tube over and around the selected element, and wherein decoupling the flexible longitudinal member from the contracting mechanism comprises rotating the tube.

7. The method according to claim 6,
wherein the tube is a first tube,
wherein rotating the tube comprises rotating the first tube,
wherein the tool further includes a second tube,
wherein the first tube is positioned within the second tube,
wherein engaging the rotatable structure with the tool comprises engaging the rotatable structure with the second tube, and
wherein contracting the implant structure comprises rotating the rotatable structure by rotating the second tube.

8. The method according to claim 2, wherein the implant structure includes a flexible contracting member that is coupled to the rotatable structure, and wherein contracting the implant structure comprises tightening the flexible contracting member by rotating the rotatable structure using the tool.

9. The method according to claim 2,
wherein the flexible sleeve has proximal and distal ends,
wherein the contracting mechanism is coupled to an external surface of the flexible sleeve within 1 cm of the distal end of the flexible sleeve,
wherein placing the implant structure into the body comprises deploying the distal end of the sleeve from a sheath and thereafter deploying the proximal end of the sleeve from the sheath, and
wherein guiding the tool along, over, and around the flexible longitudinal member comprises guiding the tool along, over, and around the selected element outside the flexible sleeve.

10. The method according to claim 2,
wherein the contracting mechanism includes a locking mechanism,
wherein the flexible longitudinal member is configured, when coupled to the contracting mechanism, to unlock the locking mechanism, thereby allowing the rotatable structure to rotate,
wherein contracting the implant structure by rotating the rotatable structure comprises rotating the rotatable structure when the locking mechanism is unlocked, and
wherein the method further comprises, after contracting the implant structure, locking the locking mechanism by decoupling the flexible longitudinal member from the contracting mechanism.

11. The method according to claim 1, wherein placing the implant structure into the body comprises placing an annuloplasty ring that includes the exactly one continuous flexible sleeve into an atrium of the body in a vicinity of an annulus of an atrioventricular valve.

12. The method according to claim 1, wherein the implant structure includes a flexible contracting member that is coupled to the rotatable structure, and wherein contracting the implant structure comprises tightening the flexible contracting member by rotating the rotatable structure using the tool.

13. The method according to claim 1, wherein a portion of the implant structure is shaped so as to define a rack, wherein a portion of the rotatable structure is shaped so as to define a pinion that mates with the rack, and wherein contracting the implant structure comprises moving the portion of the implant structure with respect to the rotatable structure by rotating the rotatable structure using the tool.

14. The method according to claim 1,
wherein the flexible sleeve has proximal and distal ends,
wherein the contracting mechanism is coupled to an external surface of the flexible sleeve within 1 cm of the distal end of the flexible sleeve,
wherein placing the implant structure into the body comprises deploying the distal end of the flexible sleeve from a sheath and thereafter deploying the proximal end of the flexible sleeve from the sheath, and
wherein guiding the tool along, over, and around the flexible longitudinal member comprises guiding the tool along, over, and around the flexible longitudinal member outside the flexible sleeve.

15. The method according to claim 1,
wherein the contracting mechanism includes a locking mechanism,
wherein the flexible longitudinal member is configured, when coupled to the contracting mechanism, to unlock the locking mechanism, thereby allowing the rotatable structure to rotate,
wherein contracting the implant structure by rotating the rotatable structure comprises rotating the rotatable structure when the locking mechanism is unlocked, and
wherein the method further comprises, after contracting the implant structure, locking the locking mechanism by decoupling the flexible longitudinal member from the contracting mechanism.

16. The method according to claim 1,
wherein the contracting mechanism includes a driving interface in a vicinity of a distal end of the implant structure,
wherein the tool is configured to engage the contracting mechanism via the driving interface, and
wherein placing the implant structure into the body comprises advancing the implant structure in a distal direction through a sheath.

17. The method according to claim 1, wherein placing comprises placing, into the body of the subject, the implant structure while the rotatable structure is directly coupled to the flexible longitudinal member.

18. A method comprising performing each of the following steps during a transcatheter procedure:
placing, into a body of a subject, an implant structure, which includes a contracting mechanism that (a) is coupled to a flexible longitudinal member and (b) includes a rotatable structure, such that the flexible longitudinal member extends outside of the body, wherein the flexible longitudinal member includes an element selected from the group consisting of: at least one wire, and a suture, wherein a proximal end of the flexible longitudinal member passes at least partially through a rotation handle, which includes a first-tube rotation knob coupled to a first tube of a tool, a second-tube rotation knob coupled to a second tube of the tool, and a control knob, which (a) when in a first position, engages both the first-tube rotation knob and the second-tube rotation knob, and (b) when in a second position, engages the second-tube rotation knob but not the first-tube rotation knob, and engages a housing of the rotation handle, thereby rotationally fixing the control knob to the housing of the rotation handle;
anchoring the implant structure to a tissue;
thereafter, guiding the tool over the flexible longitudinal member to the rotatable structure by moving the tool, by passing the first tube over the flexible longitudinal member, wherein the first tube is positioned in the second tube;

thereafter, contacting and engaging the rotatable structure with the tool, by engaging the rotatable structure with the second tube;

thereafter, contracting the implant structure by rotating the rotatable structure using the tool, by rotating the first and second tubes by rotating the control knob when in the first position, so as to contact the tissue; and

after rotating the rotatable structure, decoupling the flexible longitudinal member from the contracting mechanism by moving the control knob into the second position, and subsequently rotating the first tube by rotating the first-tube rotation knob.

19. A method comprising performing each of the following steps during a transcatheter procedure:

placing, into a body of a subject, an implant structure, which includes (a) exactly one continuous flexible sleeve, and (b) a contracting mechanism directly coupled to a flexible longitudinal member, such that the flexible longitudinal member extends outside of the body; anchoring the implant structure to a tissue;

thereafter, guiding a tool along, over, and around the flexible longitudinal member to the contracting mechanism by moving the tool;

thereafter, contacting and engaging the contracting mechanism with the tool; and

thereafter, using the tool, contracting the implant structure by actuating the contracting mechanism to pull on a flexible contracting member of the implant structure, which flexible contracting member is coupled to the contracting mechanism, so as to contact the tissue.

20. The method according to claim **19**,

wherein the flexible sleeve has proximal and distal ends,

wherein the contracting mechanism is coupled to an external surface of the flexible sleeve within 1 cm of the distal end of the flexible sleeve,

wherein placing the implant structure into the body comprises deploying the distal end of the flexible sleeve from a sheath and thereafter deploying the proximal end of the flexible sleeve from the sheath, and

wherein guiding the tool along, over, and around the flexible longitudinal member comprises guiding the tool along, over, and around the flexible longitudinal member outside the flexible sleeve.

21. The method according to claim **19**, wherein the flexible longitudinal member includes an element selected from the group consisting of: at least one wire, and a suture, and wherein guiding the tool along, over, and around the flexible longitudinal member comprises guiding the tool along, over, and around the selected element by moving the tool.

22. The method according to claim **19**, wherein placing the implant structure into the body comprises advancing the implant structure in a distal direction through a sheath while the flexible longitudinal member is coupled to the contracting mechanism in a vicinity of a distal end of the implant structure.

23. The method according to claim **19**,

wherein the contracting mechanism includes a driving interface in a vicinity of a distal end of the implant structure,

wherein the tool is configured to engage the contracting mechanism via the driving interface, and

wherein placing the implant structure into the body comprises advancing the implant structure in a distal direction through a sheath.

24. A method comprising performing each of the following steps during a transcatheter procedure:

placing, into a body of a subject, an implant structure, which includes (a) exactly one continuous flexible sleeve, and (b) a contracting mechanism that is coupled to a flexible longitudinal member and includes a rotatable structure, such that the flexible longitudinal member extends outside of the body and terminates at the contracting mechanism; anchoring the implant structure to a tissue;

thereafter, guiding a tool along, over, and around the flexible longitudinal member to the rotatable structure by moving the tool;

thereafter, contacting and engaging the rotatable structure with the tool; and

thereafter, contracting the implant structure by rotating the rotatable structure using the tool, so as to contract the tissue.

25. The method according to claim **24**, wherein placing comprises placing, into the body of the subject, the implant structure while the flexible longitudinal member terminates at the rotatable structure.

26. The method according to claim **24**, wherein the flexible longitudinal member includes an element selected from the group consisting of: at least one wire, and a suture, and wherein guiding the tool along, over, and around the flexible longitudinal member comprises guiding the tool along, over, and around the selected element by moving the tool.

27. The method according to claim **26**, further comprising decoupling the flexible longitudinal member from the contracting mechanism after rotating the rotatable structure.

28. The method according to claim **24**, wherein placing the implant structure into the body comprises placing an annuloplasty ring that includes the exactly one continuous flexible sleeve into an atrium of the body in a vicinity of an annulus of an atrioventricular valve.

29. The method according to claim **24**, wherein the implant structure includes a flexible contracting member that is coupled to the rotatable structure, and wherein contracting the implant structure comprises tightening the flexible contracting member by rotating the rotatable structure using the tool.

30. A method comprising performing each of the following steps during a transcatheter procedure:

placing, into a body of a subject, an implant structure, which includes (a) exactly one continuous flexible sleeve, and (b) a contracting mechanism coupled to a flexible longitudinal member, such that the flexible longitudinal member extends outside of the body and terminates at the contracting mechanism; anchoring the implant structure to a tissue;

thereafter, guiding a tool along, over, and around the flexible longitudinal member to the contracting mechanism by moving the tool;

thereafter, contacting and engaging the contracting mechanism with the tool; and

thereafter, using the tool, contracting the implant structure by actuating the contracting mechanism to pull on a flexible contracting member of the implant structure, which flexible contracting member is coupled to the contracting mechanisms, so as to contract the tissue.

31. The method according to claim **30**, wherein the flexible longitudinal member includes an element selected from the group consisting of: at least one wire, and a suture, and wherein guiding the tool along, over, and around the flexible longitudinal member comprises guiding the tool along, over, and around the selected element by moving the tool.

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